

Physics of Triggering

Physics of Triggering and appendixes



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33 MB

▲ a Trigger controlling the future rejection on the base of a present measurement, along two consecutive Shifting-Register areas 22 meter long lying into other Machines. Triggering is the most basic form of Measurement attributing an identity to containers. Electromagnetic measurements by mean of Laser beams over 52000 bottles-per-hour out feeding an Ultraclean Bloc

“Trigger: an event that is the cause of a particular action, process, or situation”

In the Electronic Inspectors (Bottling Controls) and in the field of Industrial Automation, however operatively-dressed, Triggers play the role of the most *elementary measurement instruments*.

Simpler than any single-channel (e.g. the High Frequency fill level inspection) or multi-channel (e.g., camera-based inspections) analog variable measurement system. To understand what really is an Electronic Inspector, we are going to analyse this most basic and ever present inspection, using it to simplify the approach to the wider field of Measurement. In the end, we’ll discover that the most modern meaning for *measurement* (inspection), does not resembles any more what we learnt decades ago in the courses of Electrical or Electronic Measurements. These complex subjects lie on the

Triggers are the most elementary measurement systems, the most basic function in all of the Electronic Inspectors

border of Technology, well into the scientific research, and are described by mathematical operators in abstract spaces. Because of these reasons, in the following we'll massively make use of visual aids: videos and figures.

Events: a historical approach to the key-concept of Trigger

In the celebrated Oxford Dictionaries of the English language, a Trigger is defined as: “an event that is the cause of a particular action, process, or situation”. It is immediately clear that Trigger's concept derives by the idea of Event, but not so evident that the Oxford Dictionaries' definition is circular. On practice, an “Event as a cause of other Events”, what in the following shall become clear. Intuitively, each one of us feels ready to answer the key question: “What is an Event ?” Desiring to understand what really is a Trigger, we look at Physics and its definition of Event. Electronic Inspectors are devices whose main task is to classify objects like: bottles, cans, crates, cases, caps, etc., after having compared the result of the physical measurement of at least one physical property of the objects, with limits established by us. After this, it is evident that Physics is not foreign to Bottling Controls, rather its core.

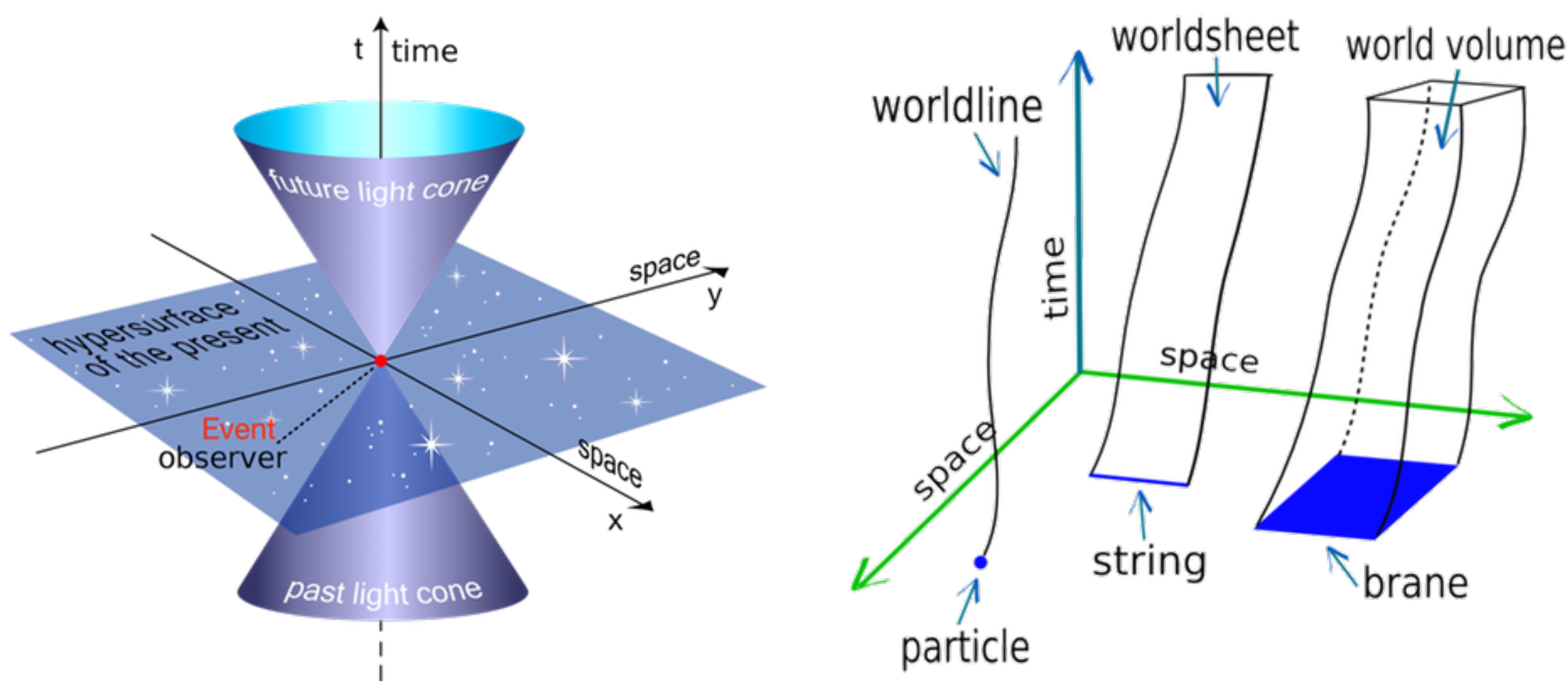
“No absolute motion exists since there are many spaces, not just one”

Hermann Minkowski, 1907

▲ since 1907 it is known that they coexist infinite 3-dimensional spaces referred to each one instant of Time

Events: triggered in a 4-dimensional space

In 1907 Hermann Minkowski, also known because having been Albert Einstein and Max Born's teacher of Mathematics in the ETH (at Zurich, Switzerland), reformulated and extended ideas of the physicist and mathematician Henri Poincare'. The result, shown in the figure below, was the first 4-dimensional system of space-time coordinates:



▲ on left side: the Event as it was conceived in 1907. The triggered Event lies along a worldline: each one dot identified by the four coordinates (x, y, z, t) of which three here shown (x, y, t). Past lightcone of the (Trigger) Event, is that one of all worldpoints which send Signals to the Event. Then, only to Events happening into the Past light cone it may be attributed a causative correlation to the Trigger Event, implying that Events happening in the volume around the bicone, about which we'll never know. The future lightcone consists of all worldpoints which receiving Signals by the Trigger Event.

On right side: time evolution of a dot (0-D), a string (1-D) and a square (2-D). All of the terms readable above were coined more than one century ago, apart “string” and “brane”, whose meaning originates in 1974 (images abridged by MissMJ, 2013)

Minkowski realized that:

- the Relativity Principle implies many times and spaces which, in turn, imply that the world we inhabit is 4-dimensional. What explained that **no absolute motion with respect to the Ether exists, since there are many spaces, not just one**;
- a body moving by inertia has to be represented by a straight timelike worldline, whereas the worldline of an accelerated body is curved;
- the acceleration of a body along a straight line in 3-D, mirrors the curvature of its worldline, as seen in 4-D;
- pairs of ordinary mechanical quantities are space and time components of 4-dimensional vectors and the ordinary electromagnetic quantities are components of new types of 4-dimensional structures.

The Event became a dot of space in the 3-dimensional surface of the Present, crossed by the Time dimension. The Time dimension perpendicular to the spatial surface in the vertex where the two cones meet, at the origin of the two space axes. Lines which intersect the surface of the Present at an angle of 45° represent light rays travelling at their characteristic maximum speed of propagation c (299 792 458 m/s). Albert Einstein, after initially dismissing his former ETH professor of Mathematics idea of spacetime in 1907, then working in the Patent Office in Bern, Switzerland, was struck by what he later called his “happiest thought”. Einstein, quite notoriously, was not a physicist advancing by formulae, rather one advancing by mean of mental images, depictions of physical phenomenas.

He was suddenly illuminated by the far reaching consequences of the mental image of a man falling off the side of a building and feeling no gravity at all, as we all know really is the case.

The choice of accelerated coordinates is enough to eliminate the effects of the Earth’s gravitational field, regardless of who or what is dropped. If gravitational force were like any other force, as an example the electromagnetism so commonly used in the Electronic Inspectors, differently charged objects would fall in different ways, some of them even accelerating upward. Remember that yet Galileo Galilei, nearly four centuries ago, observed experimentally that the reason why objects with different masses were landing in different times, had not to be ascribed to their mass rather to aerodynamic factors. By contrast, gravity appears not caring the material content: mass. From this observational fact, the *equivalence principle*, Einstein inferred that gravitation have to originate in spacetime itself. Later, he identified the property of spacetime as its curvature.

Einstein about *an infinite number of spaces in motion relatively to each other*

In 1952 Albert Einstein explained with a beatiful example the brakthrough fathered in 1907 by Hermann Minkowski about the coexistence of infinite superimposed spaces. Probably, the most clear explanation still today existing for a non-trivial concept:

"When a smaller box s is situated, relatively at rest, inside the hollow space of a larger box S , then the hollow space of s is a part of the hollow space of S , and the same "space", which contains both of them, belongs to each of the boxes. When s is in motion with respect to S , however, the concept is less simple. One is then inclined to think that s encloses always the same space, but a variable part of the space S ".

And, Einstein's personal assessment of the case:

“...there is an infinite number of spaces, which are in motion with respect to each other”

Albert Einstein, 1952



▲ When a smaller matrioska is moved into a bigger one, it is necessary to apportion to each one its particular space, not thought of as bounded, and to assume that these two spaces are in motion with respect to each other. The space

"It then becomes necessary to apportion to each box its particular space, not thought of as bounded, and to assume that these two spaces are in motion with respect to each other. Before one has become aware of this complication, space appears as an unbounded medium or container in which material objects swim around. But it must now be remembered that there is an infinite number of spaces, which are in motion with respect to each other. The concept of space as something existing objectively and independent of things belongs to pre-scientific thought, but not so the idea of the existence of an infinite number of spaces in motion relatively to each other. This latter idea is indeed logically unavoidable, but is far from having played a considerable role even in scientific thought."

What above explained by Einstein with reference to macroscopic boxes is valid until the atomic spatial scale, but with important limits. As an example, Erwin Schrödinger, when deriving the exact solutions for a Hydrogen atom in a closed and finite System, demonstrated that in this particular case, the number of bound states is finite. This implies that, also in presence of an infinite amount of spaces, only a finite amount of them allows bound states, e.g. for the matter and energy.

Events’ simultaneity

Notoriously, the notion of simultaneous Events is one of those which had to be radically revised by the Relativity theory. In the following, we’ll see how this applies in the most general case, referred to observers or, automatic measurement instruments like the Bottling Controls in accelerated motion.

All motions accelerated in a 3-D space may be conceived alike movements over a curved 4-D space-time hypersurface.

The graphic on right side is an example. Here, S is a 3-D slice of space passing thru the Event \mathcal{P} . Simultaneity is defined by a group of observers or measurement instruments a, b, c, \dots , whose world lines cross orthogonally the Simultaneity slice S and whose clocks, when crossing \mathcal{P} , read the same proper time.

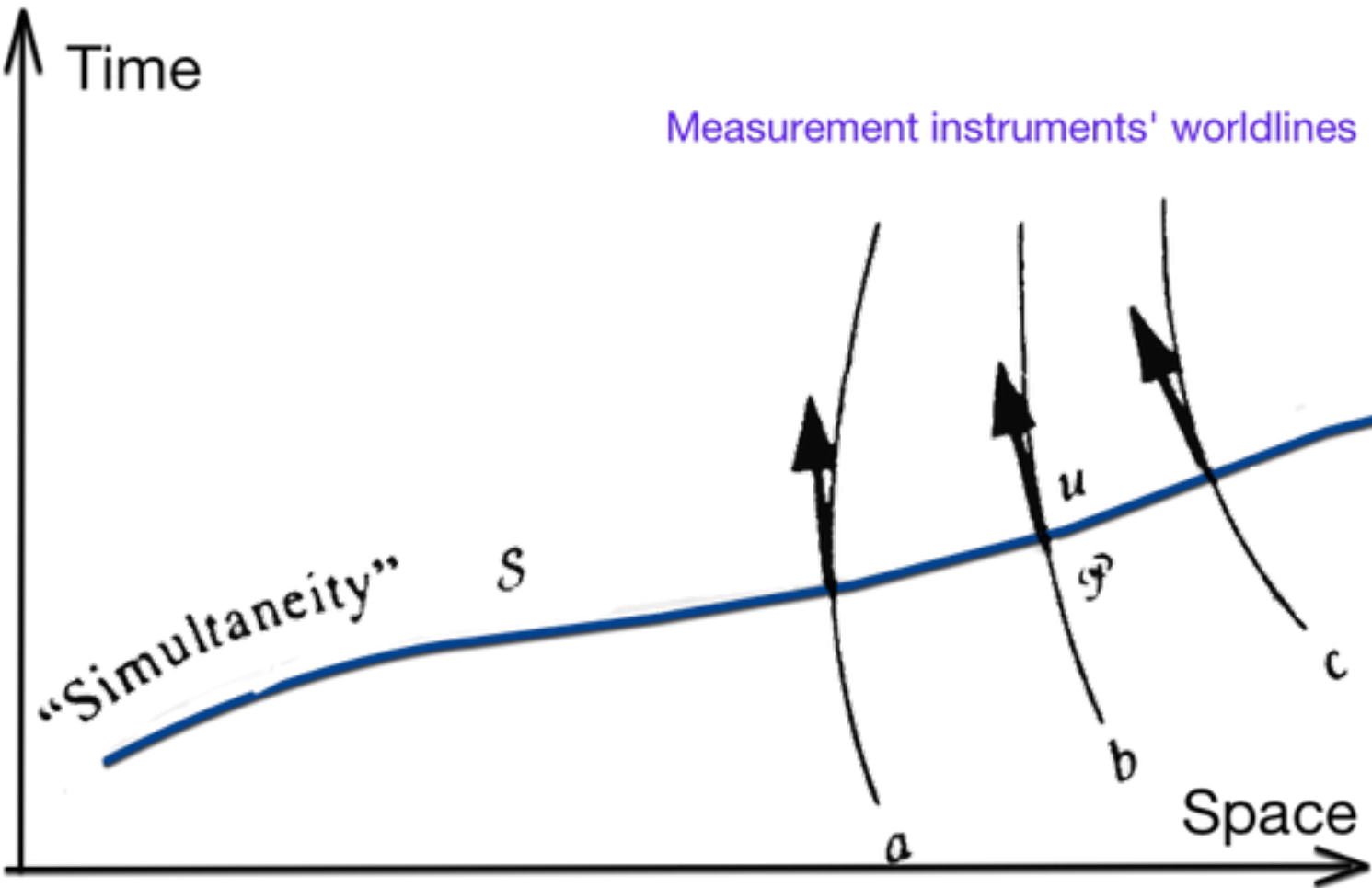
Finally, to let this one century old relativistic scenario preserve coherence with the concept of electromagnetic flux conservation, thru a single Event \mathcal{P} they can pass infinite hyper surfaces of Simultaneity, provided their:

- curvatures are different;
- and/or slopes are different;
- observers, or measurement instruments, are different;
- observers’ clocks read in \mathcal{P} a different proper time (than what read by the observers a, b, c, \dots).

In the example above, S is a 3-D slice of space passing thru the Event \mathcal{P} .

Simultaneity is defined by a group of observers or measurement instruments a, b, c, \dots , whose world lines cross orthogonally the Simultaneity slice S and whose clocks, when crossing \mathcal{P} , read the same proper time.

being moved is one of the infinite spaces in relative motion in Albert Einstein’s explanation about infinite coexisting and superimposed spaces. Erwin Schrödinger, when deriving the exact solutions for a Hydrogen atom in a closed finite System, demonstrated that in this case, the number of bound states is finite. Because of this last reason, that coexisting spaces are an infinity does not implies coexistence of an infinity of material objects, each one into each one of the infinite spaces



▲ S is a 3-dimensional slice of space passing thru the Event \mathcal{P} . Simultaneity is defined by a group of observers or measurement instruments a, b, c, \dots , whose world lines cross orthogonally the simultaneity slice and whose clocks, when crossing \mathcal{P} , read the same proper time. Interestingly, thru the same Event may pass in the meantime also a different simultaneity, by observers on a line with different curvature and/or slope, and whose clocks show a proper time different than a, b, c, ... (abridged by

The foliated character of space

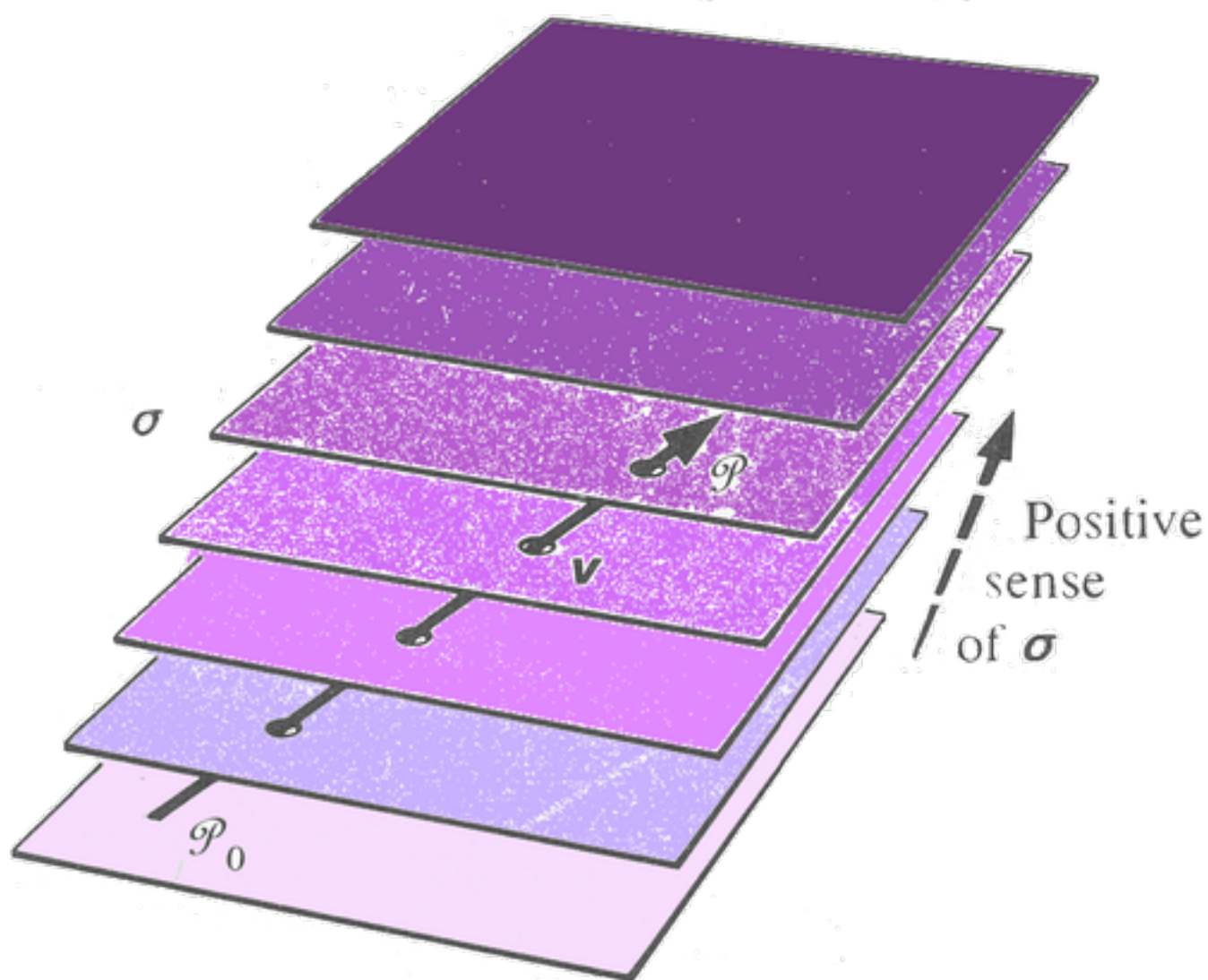
“Foliation is a serie of spatial slices of constant Time”

Event's concept changed in 1915, after Einstein applied Minkowski's ideas about acceleration, to the concepts of curvature of the space-time manifold due to density, distribution and dynamics of the masses and energy. One of the many fruits of his General Relativity theory being the capability to break up the notion of space-time into a space with time evolution, say: a **time-ordered sequence of spatial hypersurfaces**.

A first, purely geometric example of time-ordered sequence of spatial hypersurfaces in the figure down, showing:

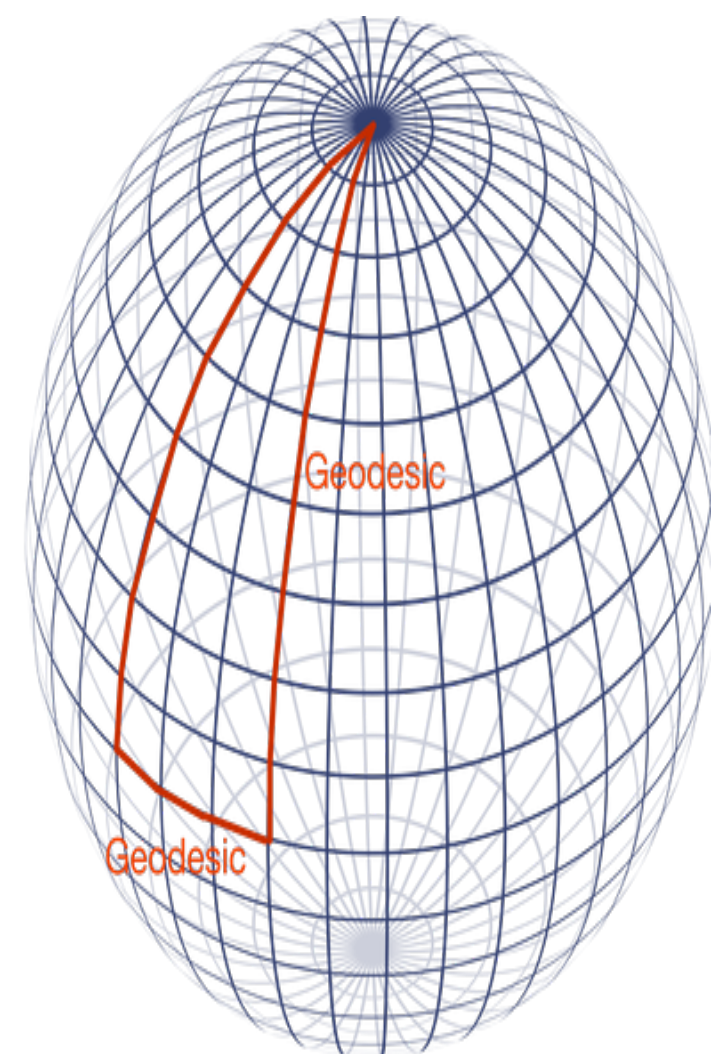
- a vector separation $\mathbf{V} = \mathcal{P} - \mathcal{P}_0$ between two neighboring points \mathcal{P} and \mathcal{P}_0 ;
- a piercing of the family σ of slices by the vector \mathbf{V} ;
- an orientation for σ necessary to define which direction from slice surface to another slice surface, has to be considered “positive” (each slice has two surfaces).

In the example presented below, the vector \mathbf{V} pierces ~ 4.5 surfaces:



▲ a first geometrical example of foliation where slices' separation is purely parametric (abridged by Wheeler, Thorne, Misner, 1973)

Geodesics basic



1. they do not exist straight lines
These are limits reached when the curvature of the hypersurfaces $\Rightarrow 0$.
The physical space is curved and the equivalent of the straight lines of a flat geometry are “geodesic”
2. geodesic are arcs of great (maximum) circle;
3. the shortest line joining two points in a curved geometry;
4. each one worldpoint is crossed by at least one geodesic;
5. two Events may be connected by more than one geodesic.

▲ **Dynamical effects are what we and our measurement instruments perceive along the Time (horizontal) axe. On the microscale the texture of each leaf of space is not fixed, rather rapidly fluctuating & bulging out in knots and holes**

Applying these concepts to the physical space-time, a slice is a surface of constant Time.

The figure below on right side describes a Foliation of the space-time manifold \mathcal{M} , which better represents the reality than the one we examined before, derivating by the one century old Minkowski's flat-space \mathcal{M}_0 :

- bumps, wiggles and waves due to the presence of matter and fields energy;
- Event on the slice Σ at the Time t ;
- an adjacent posterior space-like slice Σ , referred to the Time $t + dt$.

The Time coordinate parameter t is only a freely chosen label to distinguish one spacelike hypersurface from another. Then, is this the answer to the fundamental question: ...*what is a Triggered Event* ? It is a label (or marker, or identifier) applied to a worldpoint part of an one-parameter hypersurface in a family of hypersurfaces. The *proper time* s referred to the Event, is measured along the worldline crossed by the bicone vertex. The Reader is now suggested to recall some of the properties ruling the hypersurface of the Present, seen in the precedent figure. No transmission of electromagnetic Signals or movement of matter, happens thru the individual slice, rather thru different slices (or, leaves or sheets) of the Foliation.

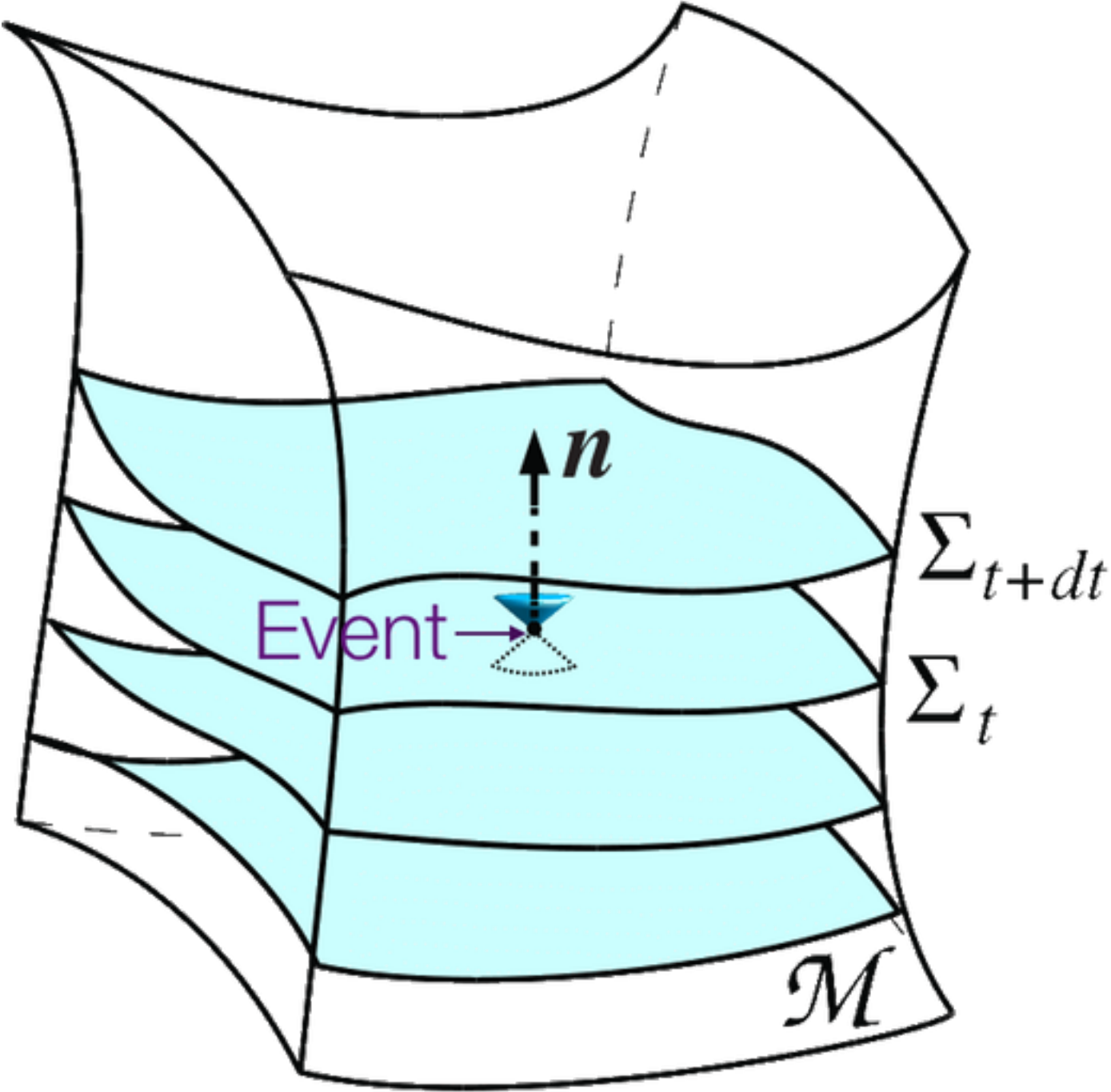
Matter and Signals were considered transferred only toward the Future light cones when General Relativity was created. Following the modern insights of Quantum Physics, we know that on the microscale of dimensions they are also transferred into the Past light cone, forming Closed Timelike Curves (CTCs) of extremely brief duration. Moreover, the Special Relativity defines strict successions of Events. On the opposite its extension, the General Relativity theory, considers the 4D space foliated by 3D leaves. The Time reduced to a mere indicator of the position of the individual leaf with respect to the foliation. In the modern relativistic scenario, and several densely dotted Events have not an univoque

What is a Triggered Event ?

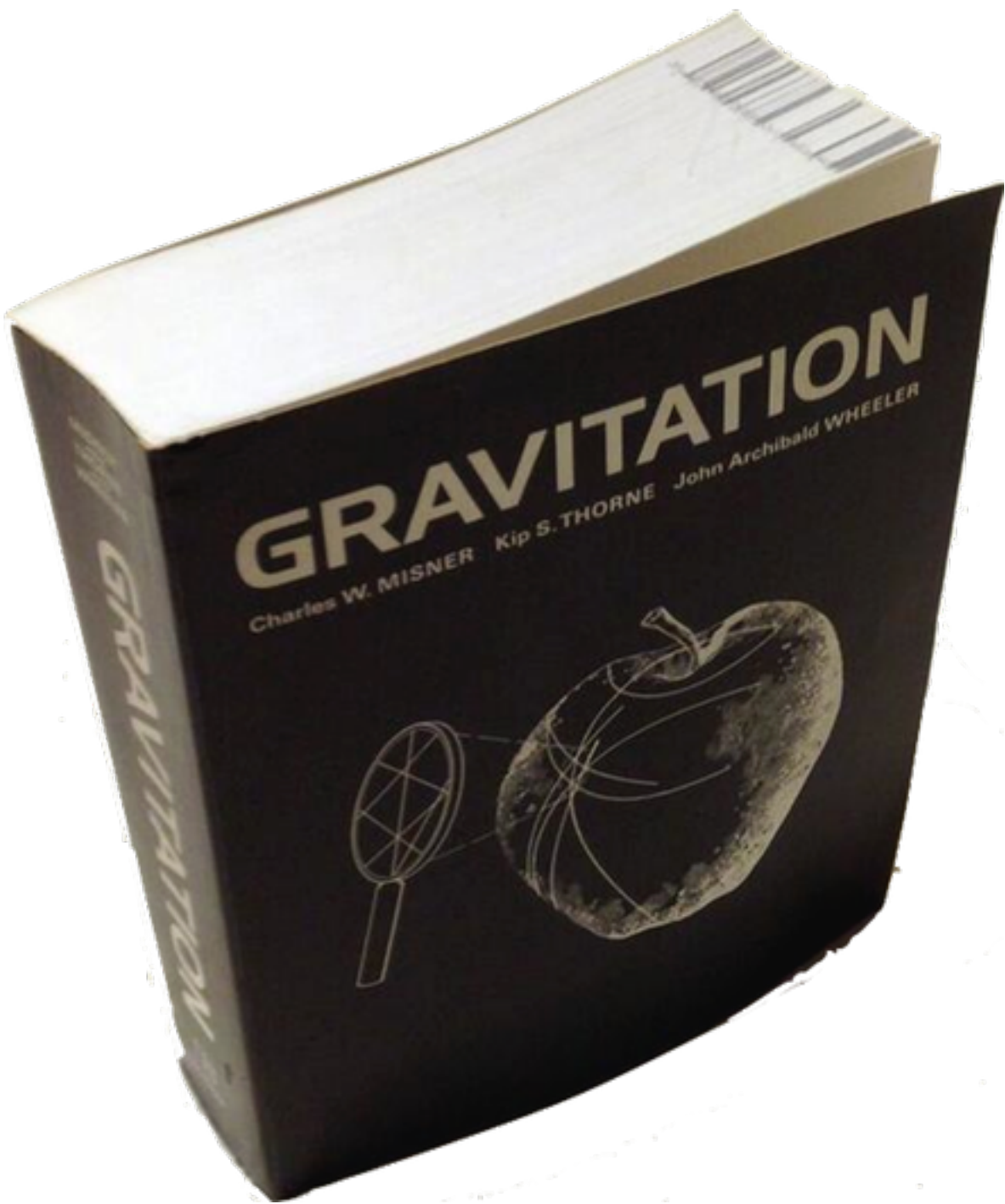
General Relativity point of view 1:

"it is a label applied to a world point part of an one-parameter hypersurface, in a family of hypersurfaces"

Right side: the Event after 1915 and til ~1960 is a worldpoint in a spatial-only leaf (or slice, or sheet) part of a foliation: the manifold \mathcal{M} . The manifold is a serie of leaves. Each leaf is a surface of constant relativistic coordinate time (t, in the figure). The Event, at the vertex where the two light cones meet. The slices are curved because part of a spacetime fabric is warped by its own mass-energy content. In the most general case, the slice where the Event happens contains all the space, matter and energy existing in a Universe subspace. The Event acquired the meaning of a worldpoint where it happens an exchange of energy



Left side: *Gravitation*, by J. A. Wheeler, C. W. Misner and K. Thorne. Since 1973 with its 1300 pages, the worldwide standard academic textbook of General Relativity



production of pairs electron-positron $e^- e^+$ when sufficient energy is available. This, implying that Trigger Events in one slice (or, leaf) gives their effects in other slices or leaves. Between 1915 and 1973, the meaning *Event* acquired may be inferred by the figure below, adapted by the celebrated worldwide main textbook of General Relativity, *Gravitation*, by J. A. Wheeler, C. W. Misner and K. Thorne, 1973. *A Physical Event like the geometric world-point where it happens an interaction or, exchange of energy.*

This, however dated, is the definition of Triggered Event (or, Measurement), still today applied in the Food and Beverage Bottling Controls, the Electronic Inspectors, and in the Automation Technologies whose applications are still more widespread in the Food and Beverage Packaging Lines.

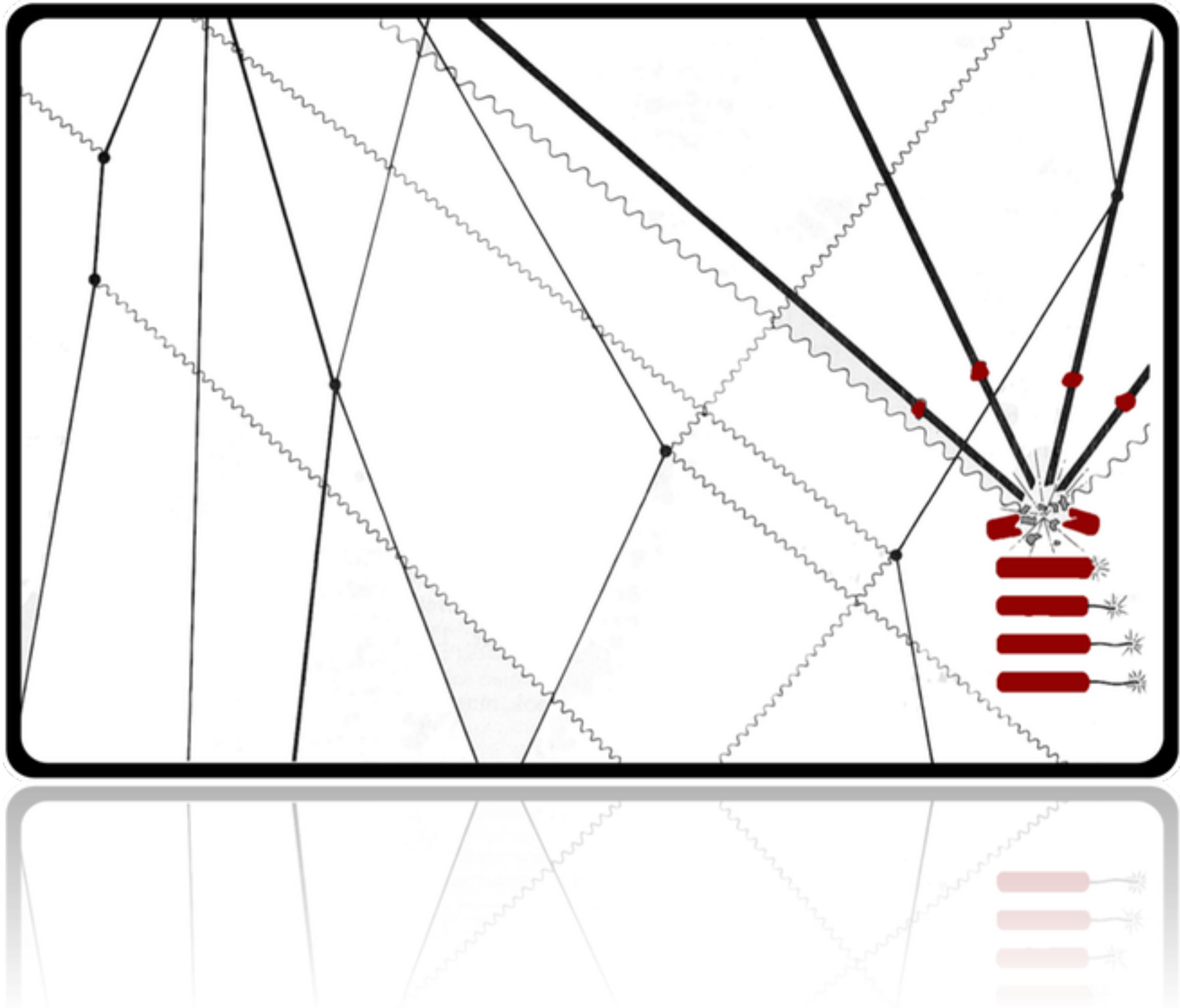
On left side: "The crossing of straws in a barn full of hay is a symbol for the worldlines that fill up space-time. By their crossings and bends, these world lines mark Events with a uniqueness beyond all need of coordinate systems or coordinates. Typical Events in the diagram, from left to right (black

dots), are: absorption of a photon;
reemission of a photon; collision
between a particle and a particle;
collision between a photon and a
particle; another collision
between a photon and a particle;
explosion of a firecracker and
collision of a particle from outside
with one of the fragments of that
firecracker (original quote
by Wheeler, Misner, Thorne, 1973)

The Events listed in the caption on
left side of the figure above are
those originating the Signals which
all of the Food and Beverage
Bottling Control devices:

- detect;
- amplify;
- integrate, along times long
enough to pass over the
thresholds of sensitivity;
- conduct in the end the Binary
Classifier to *reject*.

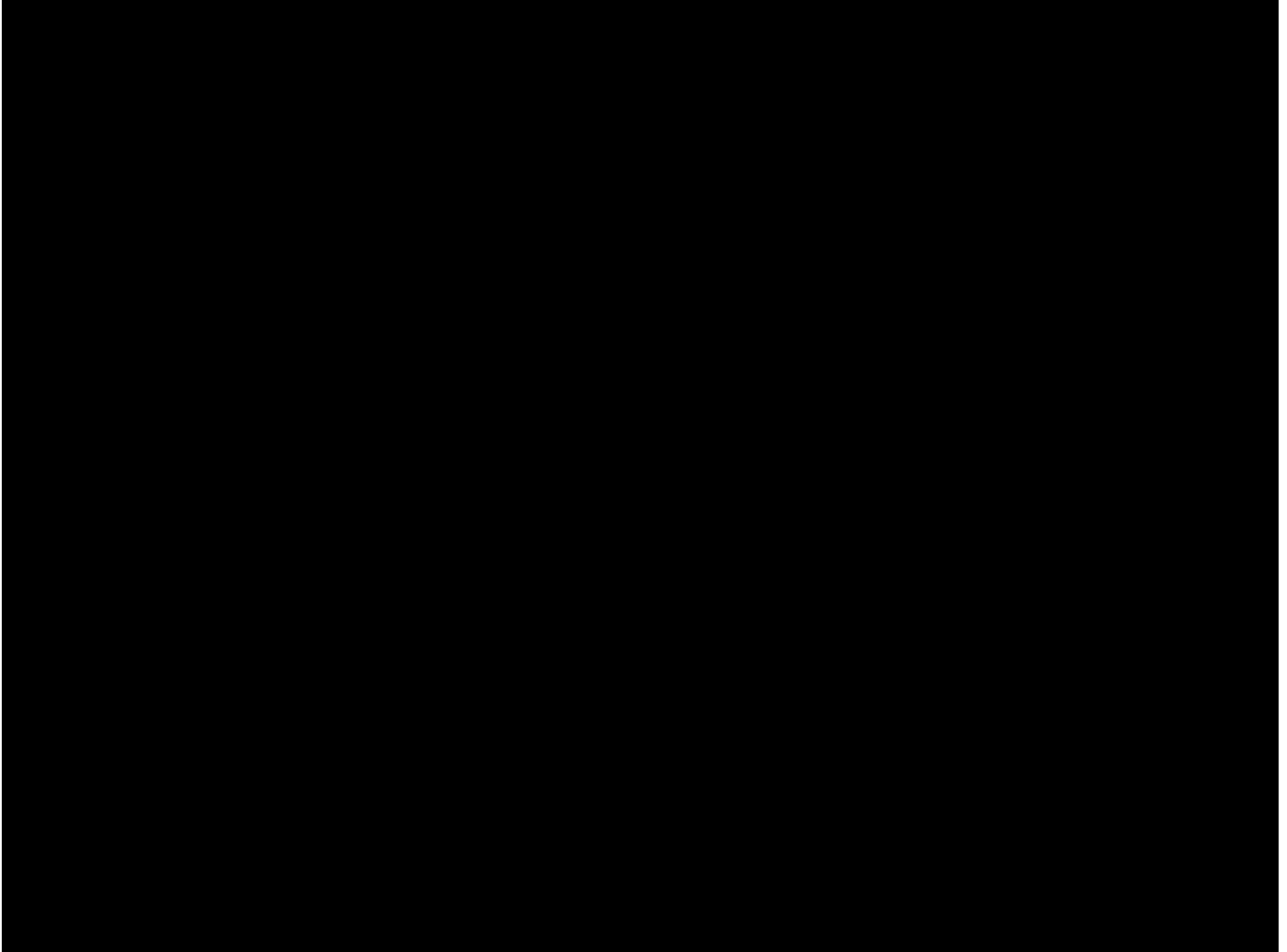
The idea underlying these figures is the one of *interaction*. All interactions which affect matter
particles are due to an exchange of force carrier particles, a different type of particle altogether.
What we normally think of as *forces* are actually the effects of force carrier particles on matter
particles. Force carrier particles whose exchange results in attractive or repulsive effects, a
process hinted by the video animation here below:



What is a Triggered Event ?

General Relativity point of view 2:

*“it is a point of space-time along
a geodesic, where it happens an
exchange of energy”*



▲ all interactions which affect matter particles are due to an exchange of force carrier particles, a different type of particle altogether. “Particles” a mere dotlike idealization of real waves of energy. What we normally name *forces* are actually the effects of force carrier “particles” on matter “particles”

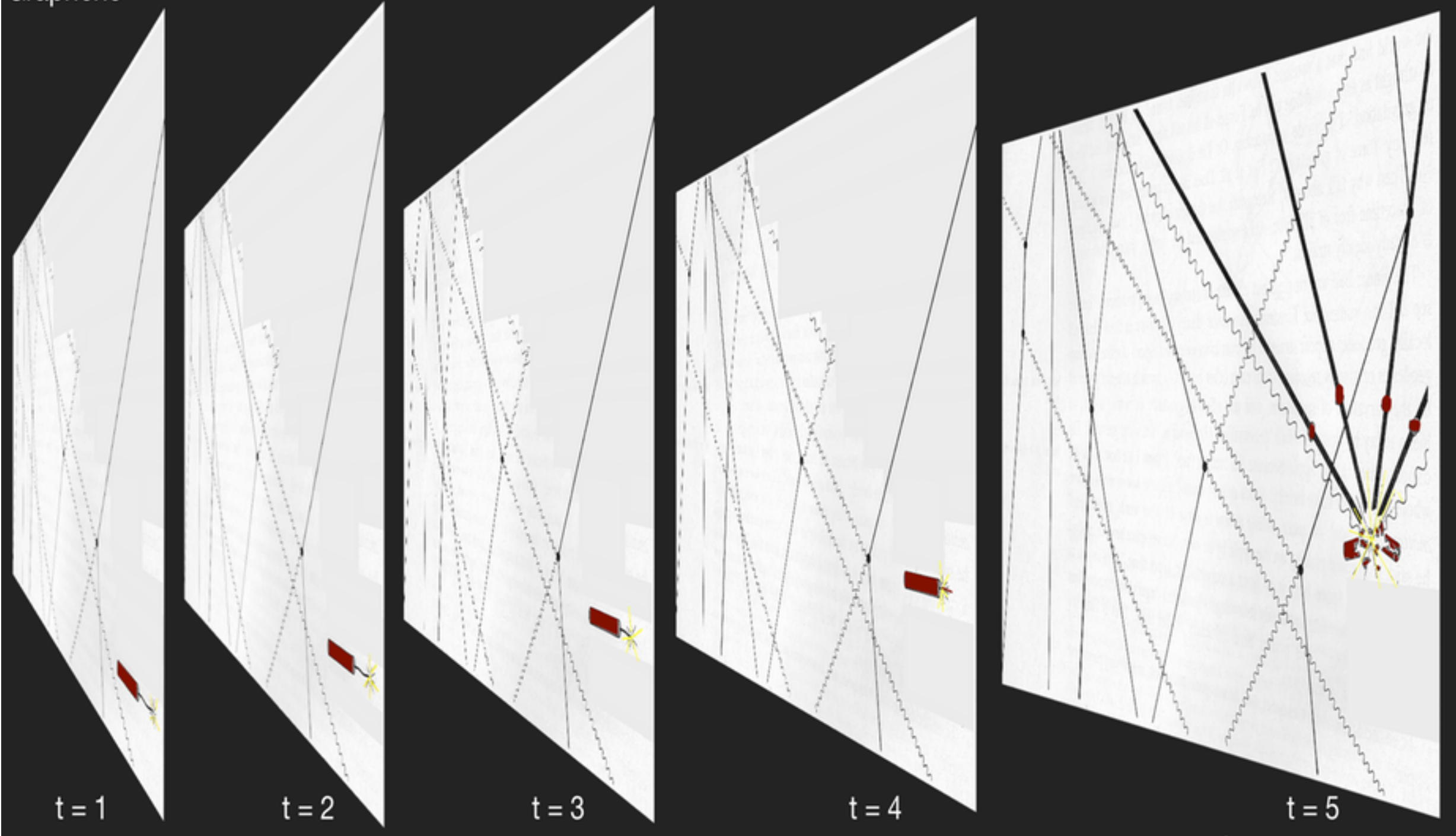
The figure with the firecracker above is just a compact representation, corresponding to five superimposed slices, what can be perceived after its comparison with the figure below. Above, all Events, Triggerings Events and inspections, they all happen in a space-time slice where all of the dots of space are referred to a single constant Time, part of a foliation of the 4-D structure. The fine-details are a subject out of the scope of this web page devoted to the physical measurements (inspections) in the Beverage Bottling Lines.

An example of this is referred down in the following figure. Here, five Events, as seen by Physics point of view between 1915 and ~1960, associated to five different consecutive times. Imagine these five slices as transparent foils. Superimpose them and you’ll have the single diagram in the precedent figure, in the start of this page. In this dated point of view, the five slices below are spacelike hypersurfaces of constant time. They constitute a Foliation. In this dated image, one deeply changed only a few years later in mid-60, each slice has at least a detail making the difference with respect to the other four slices, meaning they cannot exist two identical slices. If two slices should have same identical content of matter and radiation, something in principle not impossible however unreasonable, then the mere difference in their common constant Time should however be enough to differentiate them. In the case depicted below, five different statuses of consumption of the string are the detail making the difference between one slice and the others. This considered, triggers' most basic definition reduces itself to *devices to label the statuses of physical or logical entities*.

What is a Triggered Event ?

General Relativity point of view 3:

"a device to calculate and constructing a leaf of history that slices through the higher dimensional space"



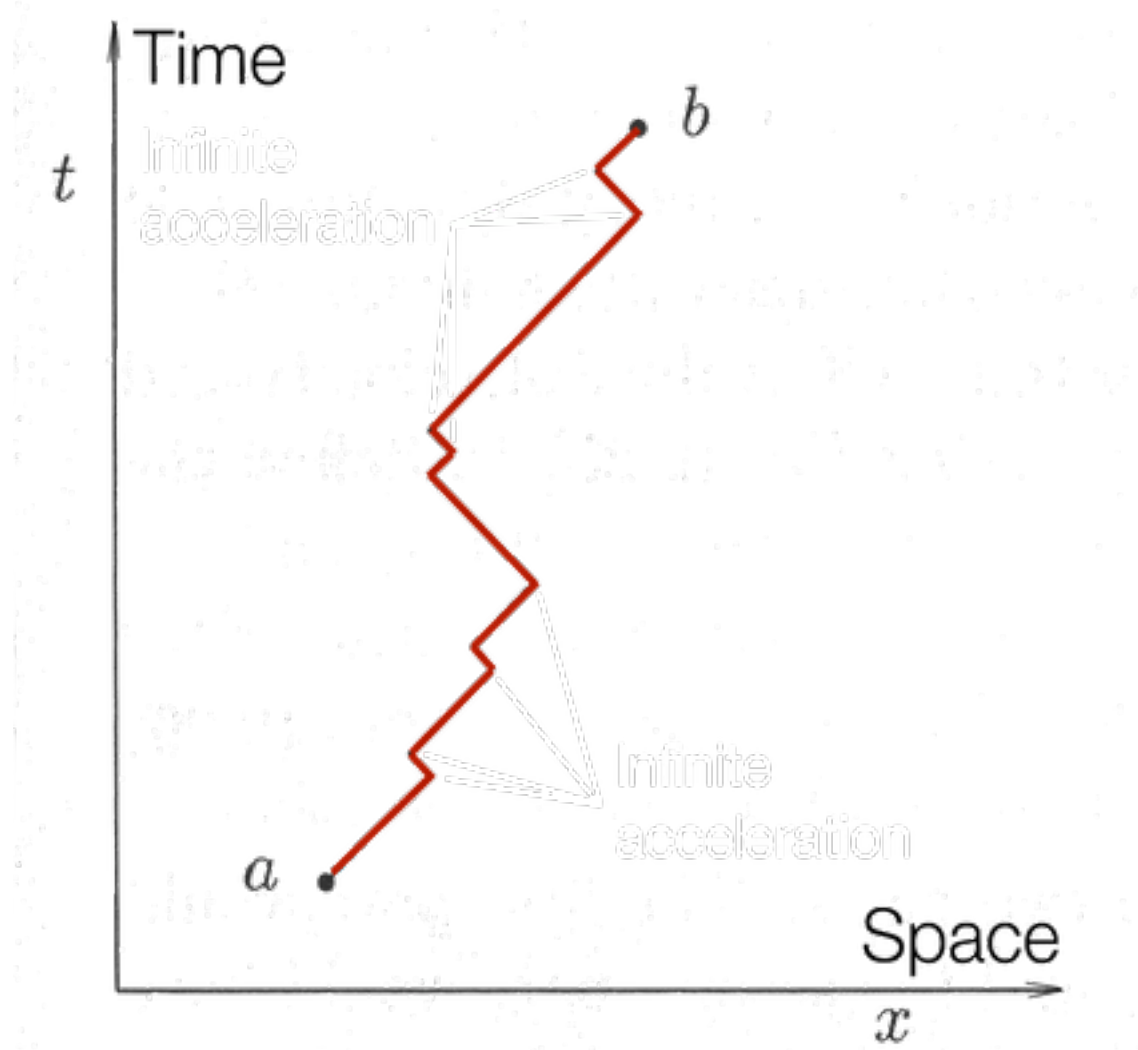
▲ **Five Events, as they were imagined between 1915 and ~1960, associated to five different consecutive times. Imagine these five slices as transparent foils. Superimpose them and you'll have the single diagram in the precedent figure above. The slices are spacelike hypersurfaces of constant time; jointly constitute a Foliation. Each slice has a detail differentiating it with respect to the others. Five different statuses of string's consumption are the detail making the difference between slices (image abridged by J. A. Wheeler, C. W. Misner, K. Thorne, 1973)**

Triggered Event as sum over histories

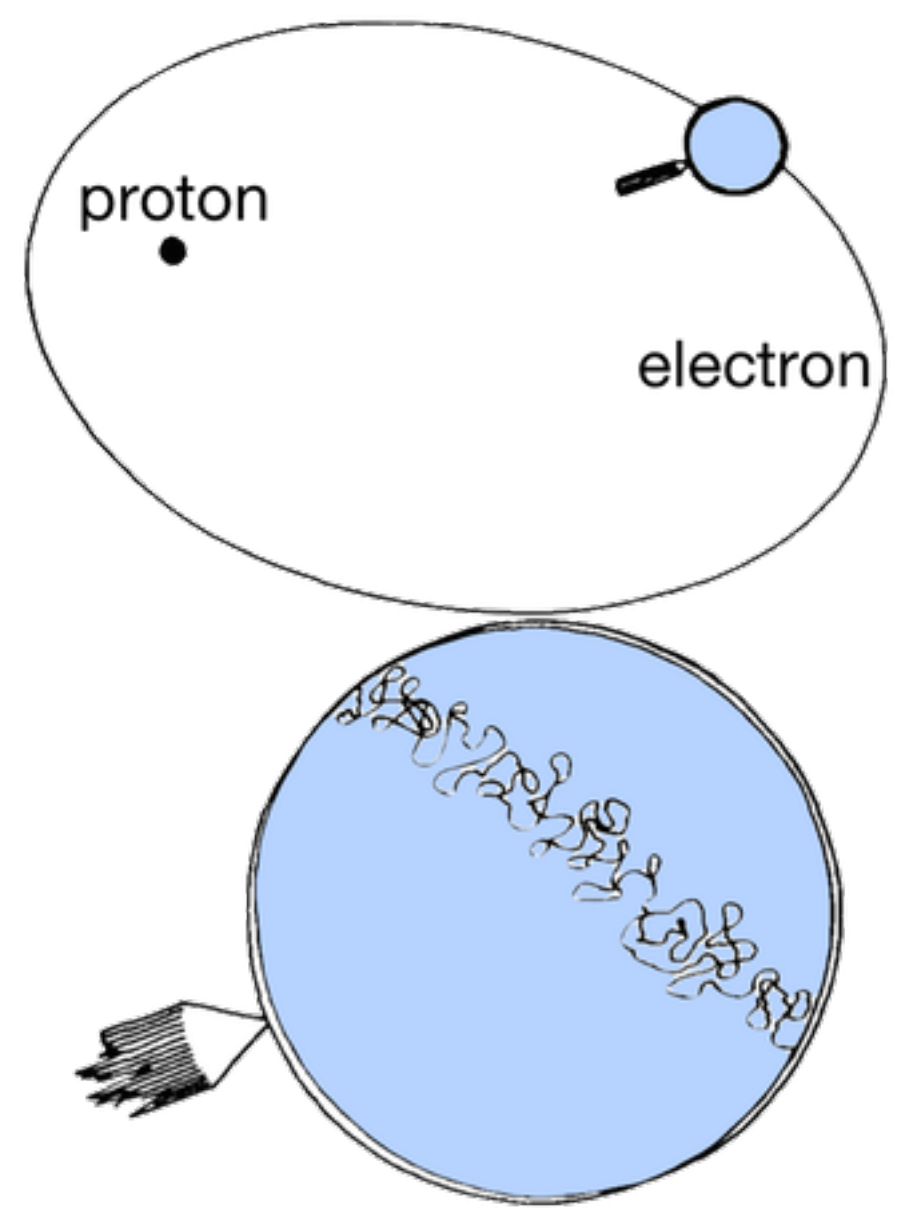
Introduction

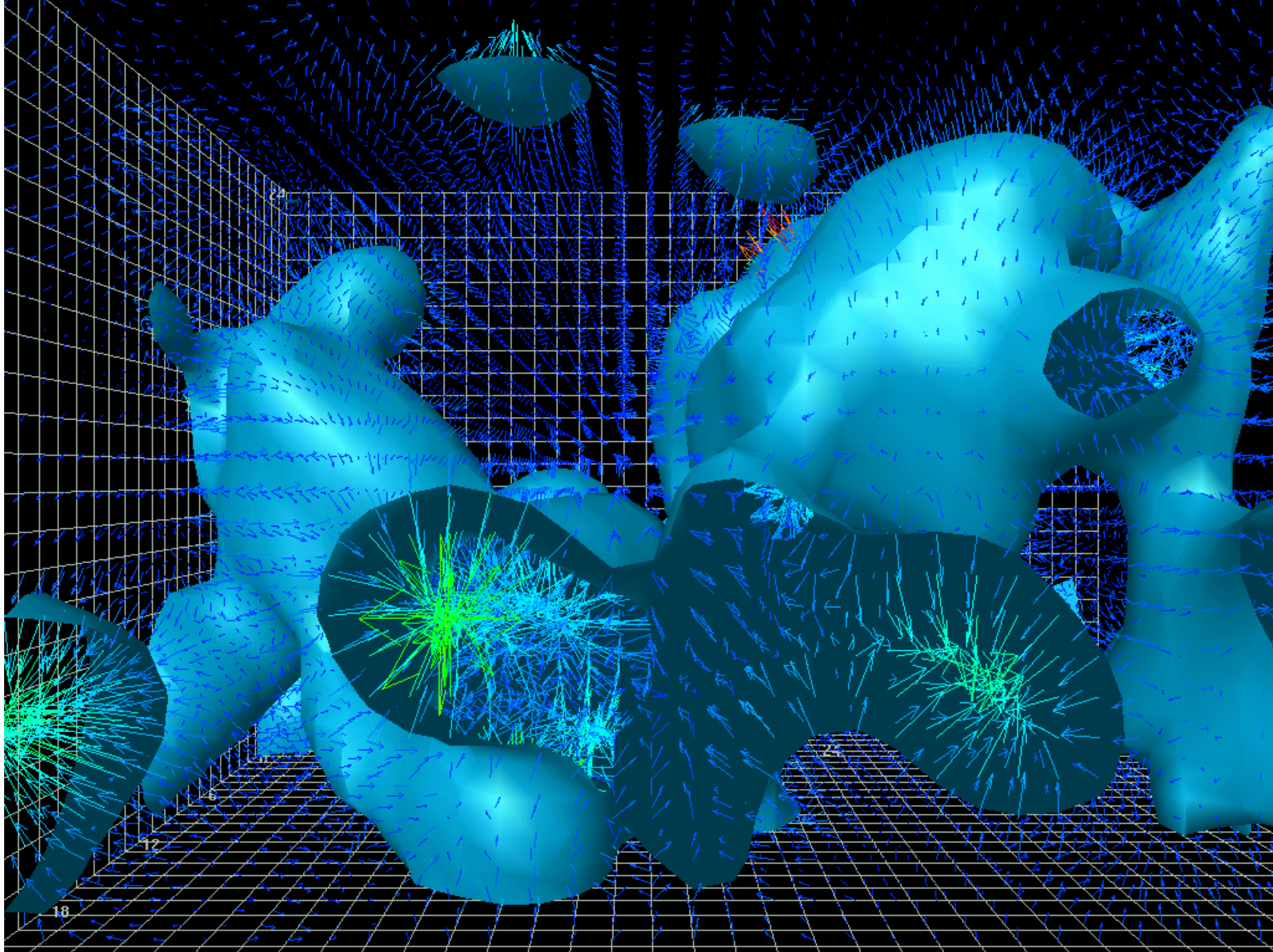
We are going to start this section proposing you to imagine what you'd see if you could magnify details $< 10^{-30}$ cm. As an example, the *orbit* where Rutherford 110 years ago assumed the electron of the Hydrogen atom to be revolving a nucleus. The effects of this permanent and randomly oriented oscillation of the electron are known since then. Effects hinted in the figure below, on right sid: no orbit at all ! It lies in this posterior observation one of the main *reasons why Quantum Mechanics had to be created* replacing the newtonian Mechanics. It was not an academic exercise: the progress of theories and their comparison with experimental and technological facts, around the end of the Nineteenth Century implied also a progressive divergence of what was considered causing what else. The motion of a particle, yet in the basic unidimensional case below on left side, is an example of this departure from the Classic concepts.

Below: magnifying the orbit where the electron of the Hydrogen atom was assumed 110 years ago to be revolving a proton, discloses an unexpected scenario. No orbit at all (image abridged by C. M. DeWitt, J. A. Wheeler, 1967)



▲ The trajectory of a relativistic particle, traveling in one dimension, is a zig zag of straight segments, whose slope is constant in magnitude. The difference lies in the sign from zig to zag. In each one of the corners the acceleration is infinite, implying that the concept of ‘trajectory’ of the Classical Mechanics, however familiar it may be, does not applies (abridged by R. P. Feynman, A. R. Hibbs, 1965)





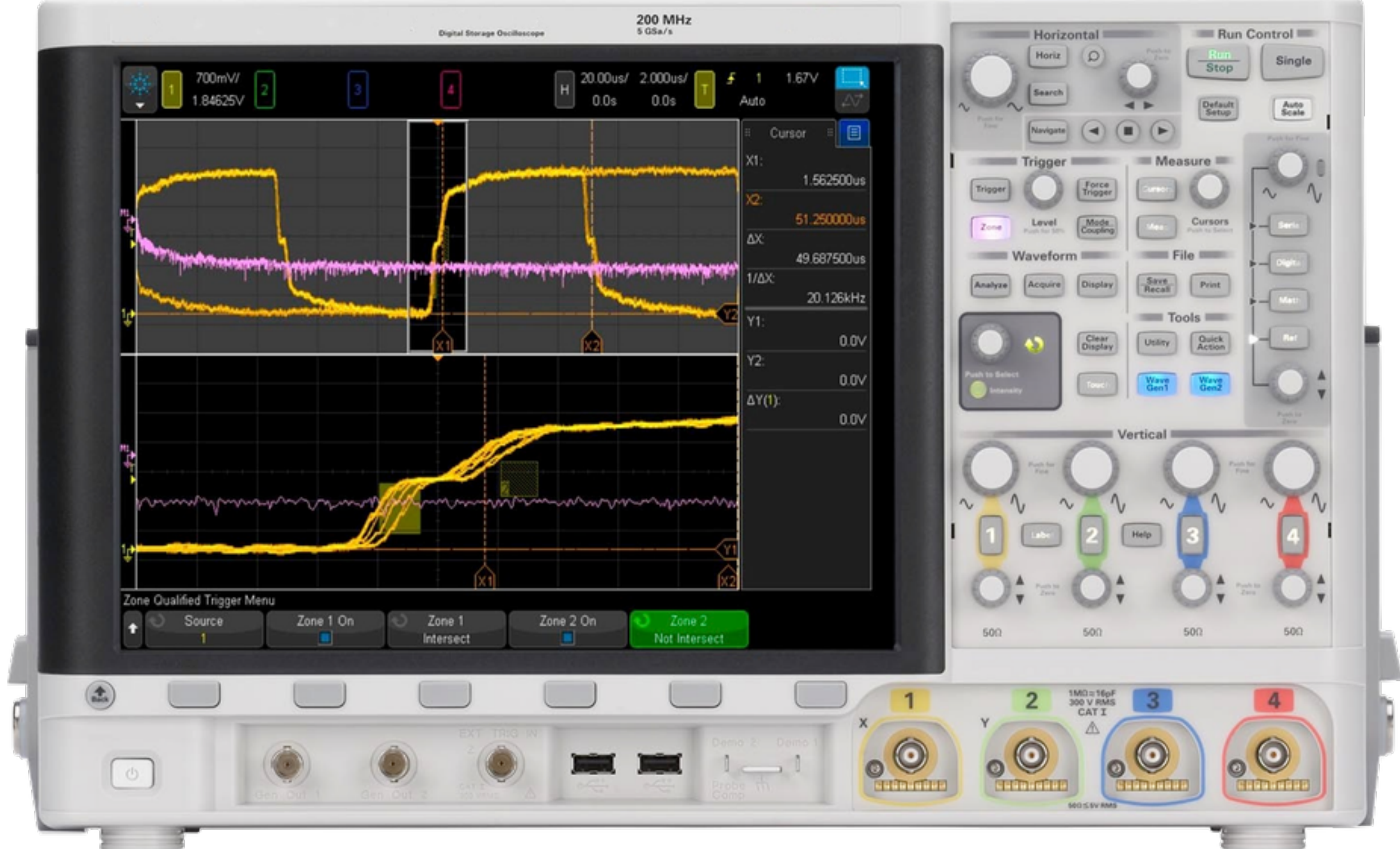
▲ **Zero-Point** field random oscillations permeate all the space. They are observed also freezing an ambient a few thousandths of kelvin degree over the absolute zero, implying that their origin is non thermal. Cutting to 1 mm the metallic sensible part of the probe of a common oscilloscope, allows to measure what the animation tries to show. Fluctuations whose energy density reaches peaks of 10^{83} tons/m³ (image credit W. Brown, 2012)

The electron is affected by fluctuations of the electric field in vacuum (also named “ground state” or “zero-point” fluctuations), creating displacements with respect to the theoretical curve a true orbit should imply. Displacements nil on average, but huge when considering their root mean square. Then, the electric field truly felt by the electron is not the static one supposed around the (positive) proton. Zero-Point field random oscillations permeate all the space: they are not a feature of the matter, rather of the space itself.

They are observed also freezing an ambient a few thousandths of kelvin degree over the absolute zero, implying that their origin is non thermal. To detect them and to measure what the animation above tries to show, is not necessary complex Laboratory equipment. In the following a practical example.

“Zero-Point field random oscillations permeate all the space: they are not a feature of the matter, rather of the space itself”

Example 1. Electromagnetic field fluctuations



Imagine a common oscilloscope like the one here above:

1. Expose the 1 cm long metallic tip of its probe (an example in the figure below) to the electromagnetic field of a distant source, whose frequency is 1 MHz. Imagine a magnetic field B , measured where the oscilloscope's probe emulates an antenna, amounting to 10^{-8} gauss.
2. For a spatial domain of this size, oscillating at that frequency, the fluctuation of the em field amounts to only $\sim 10^{-17}$ gauss. Say, it is one hundred millions times smaller, then definitely impossible to detect, lost in a sea of *noise*.

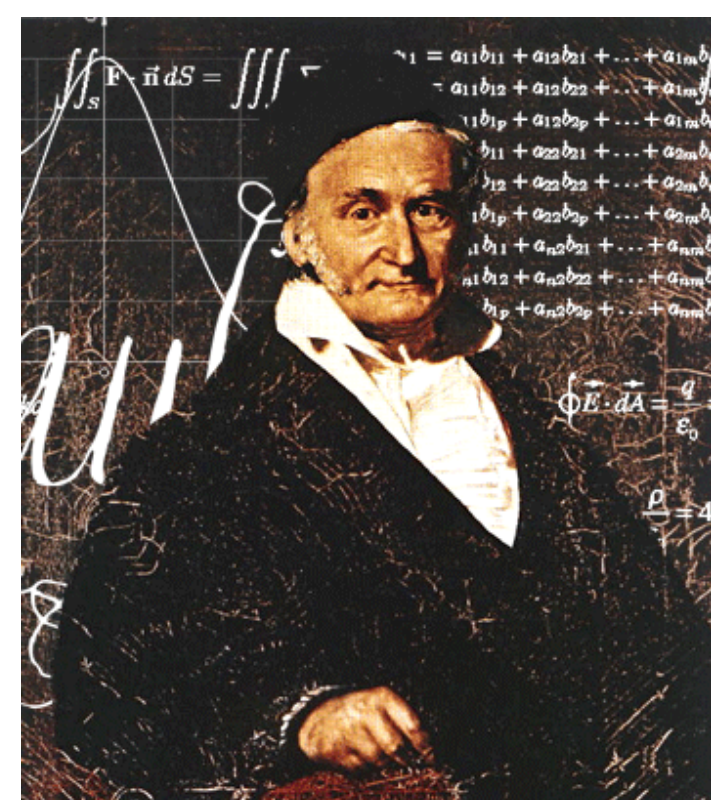
Repeat the test after having cutted to < 1 mm the metallic exposed part of the probe:

1. the quantum fluctuations dominates for an order of magnitude over the classically expected em field, amounting to $\sim 10^{-7}$ gauss. Cutting 10 times the length of the probe, we reduced the amount of mass-energy and space in the meantime.

Conclusions:

The spatial domain, also when emptied by mass-energy (e.g., the matter of the probe metallic tip) has its own electromagnetic field, and this results now ten times bigger than that induced by a power trasmitter. Space's true nature starts to show itself.

▲ All oscilloscopes are capable to detect signals at frequencies of 1 MHz. They allow a direct sight to the discontinuity existing between the world of the illusions derived by our sensations and the reality (image credit Agilent Technologies®)



▲ Carl Friedrich Gauss, astronomer, physicist and mathematician. To him is entitled the magnetic field unit



On left side: reducing the length of the metal tip of this probe to 1 mm. You'll start to witness and measure the electromagnetic counterparts of the natural quantum fluctuations of that limited space. Appearing like an electrical *noise* originating by an em-induced signal whose amplitude is approx. one tenth of millionth of gauss. The space where Electronic Inspectors' measurements are carried on, is a multiply connected foliated structure. Its energy density fluctuations reach the impressive value $\sim 10^{83}$ ton/m³ (abridged by image credit Pico Technology®)

Example 2. Geometric fluctuations

Until now we have frequently named concepts like:

- curvature of the geometry,
- curvature of the space,
- 3-dimensional geometry,
- 4-dimensional spacetime.

The yield of these terms is frequently underestimated. But after 1915 they refer to quantitatively defined amounts. Amounts whoever feels directly, like the gravity, and can easily measure with small field devices named gravimeters. Gravimeters are equipments commonly used to measure variations in the Earth's gravitational field. This last, a synonymous of the tidal effects due to the curvature and other peculiarities of the geometry of the space at the surface of the Earth. The field is not static, but varies continuously with time because of the movement of the masses.

The masses being primary sources of gravity variation are:

- tides,
- hydrology,
- land uplift/subsidence,
- ocean tide loading,
- atmospheric loading;
- changes in the Earth's polar ice caps;
- Sun;
- Moon;
- planets.

A number of different mechanical and optical schemes exist to measure this deflection, which in general is very small. One of these consist of a weight suspended from a spring; variations in gravity cause variations in the extension of the spring. Variations in the

Earth's gravitational field as small as one part in 10 millions can yet be detected. Also, it exist a version capable of absolute measurements of gravity. In these models the measurement is directly tied to international standards, and this is what makes them absolute gravimeter. The measured accelerations can be converted into absolute measurements of the curvature of the local geometry by mean of relativistic formulae. A professional model of these appears on right side. Its performance specifications may be resumed in its impressively small amount for the accuracy: 2 μGal . Gal is a non-SI unit of acceleration used extensively in the science of gravimetry, defined as 1 centimeter per second squared (1 cm/s^2).

For the same 1 cm (initial length of the oscilloscope probe) domain we used in the precedent example, the fluctuations of the curvature are negligible ($\sim 10^{-33} \text{ cm}^{-2}$). One hundred thousands times smaller than the curvature of the space at the surface of the Earth ($\sim 10^{-28} \text{ cm}^{-2}$) that an instrument like the gravimeter on right side easily measures. This time, reducing ten times or one billion of billions of times the spatial extent of the domain, the fluctuations continue to be negligible by the gravimeter.

We are witnessing a real *divide* existing between the:

- **electromagnetic forces**, object or medium of all of the Electronic Inspectors' measurements;
- **gravitational forces**, however existing where our em measurements are accomplished.

A *divide* whose origin started to be understood only in 1996, object of deeper analysis in the last sections of this pages.

Final conclusions

The complexity of these effects hints to the fact that space, at small scale, is not as regular, simple or smooth as it was imagined and still it is supposed. In the real world of Quantum Physics one cannot give both a dynamic variable and its time rate of change, because forbidden by the Uncertainty Principle. This implies that no meaning exists for what intuitively each one of us consider senseful: the history of the material and radiative content of space, evolving in time.

Quoting Wheeler, Thorne and Misner's perspective dated 1973:

“The concepts of space and time are not primary but secondary ideas in the structure of physical theory. These concepts are valid in the classic approximation (...) There is no space-time, there is no time, there is no before, there is no after. The question of what happens next is without meaning”.



▲ This device is the world's most sensible and precise commercial gravimeter. Its accuracy amounts to an acceleration of $0.000\,001 \text{ cm/s}^2$. Its accuracy is however not enough to detect the fluctuations of acceleration originating by the changes on Topology happening on the smaller scales. As a consequence, these do not influence at all the result of the measurements of the Electronic Inspectors, which are electro magnetic or, mediated by electro magnetic forces. The reason started to be understood only recently, in 1996 (abridged by image credit Microg Lacoste®)

The deep meaning of *sum over histories*

After 1948 it started to be adopted the idea that an Event refers to the results just after a fundamental interaction took place between subatomic particles, occurring in a very short time span and at a well localized region of space. But, because of the Uncertainty Principle, the signification is no more univoquely defined, rather probabilistic. This point of view, named 'Path Integrals', is mainly due to the nobelist Richard P. Feynman (see figure on right side). He solved in modern times the paradox evident in an ancient experiment of Optics, named after Thomas Young.

He proposed (see figure below) that *...all of the possible alternative paths allowed to particles, from a source to a detector, contribute to define the probability amplitude of the Event we name 'detection'*. As a matter of fact, if we are still considering senseful the Dictionary definition of Trigger, the detector itself is a Trigger. In this new scenario, the probability amplitude for an Event is the sum of the amplitudes for the various alternative ways that the Event can occur. In the figure down, there are several alternative paths which an electron may take to go from the source to either hole in the screen C.

The then imagined *alternative* paths, were conceived like time-ordered (left to right) sequences **[1]**:

- Source > Event 0 > Event 1 > Event 5 > Event 8 > Event 10 > Detection
 - Source > Event 0 > Event 2 > Event 6 > Event 9 > Event 11 > Detection
 - Source > Event 0 > Event 3 > Event 4 > Event 7 > Event 10 > Detection
 -
- [1]

A simple sight to the system in the figure below allows the preception of the combinatorial character of this approach: different paths are different combinations of Events. Quoting Feynman's words transmits the reality of the electron passing thru a barrier of potential:

"The electron does anything it likes. It just goes in any direction at any speed, forward or backward in time. However it likes, and then you add up the amplitudes and it gives you the wave-function".

On left side: "When several holes are drilled in the screens E and D placed between the source at screen A and the final position at screen B, several alternative routes are available for each electron. For each of these routes there is an amplitude. The result of any experiment in which all of the holes are open requires the addition of all of these amplitudes, one for each possible path" (original quote of the diagram above in 'Quantum Mechanics and Path Integrals', Richard P. Feynman)

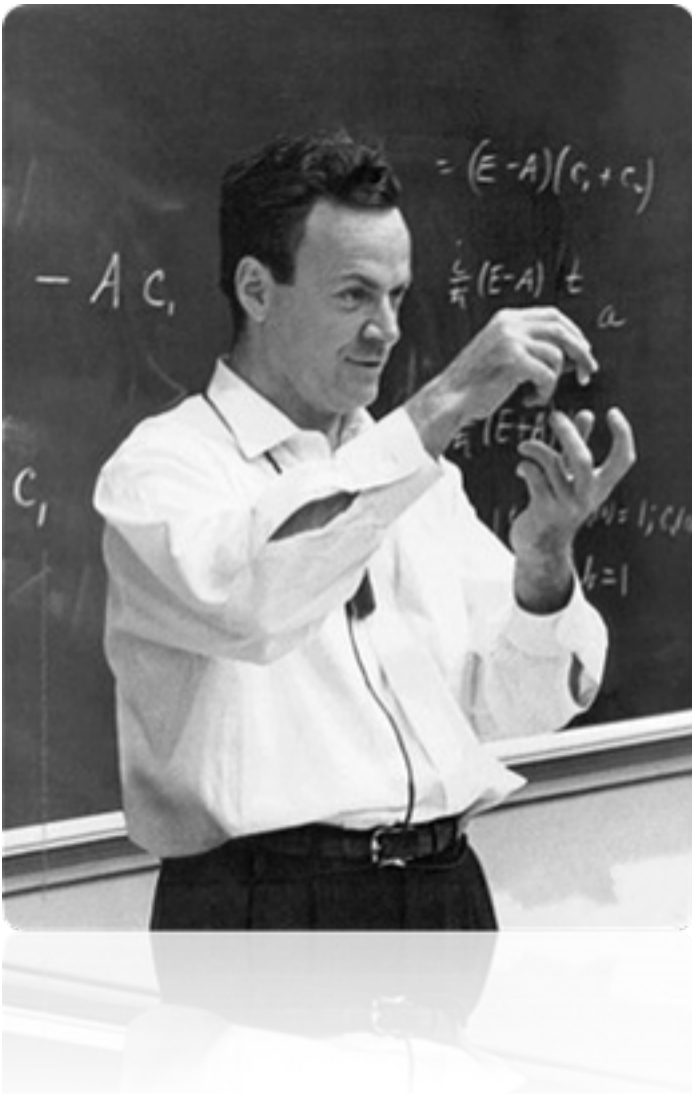
The key point is that the transition to Quantum Physics implied to assign a probability amplitude to each possible geometry, spread over all of the higher dimensional space. An amplitude higher close to the classically forecast leaf of history and falling off steeply outside a zone of finite thickness briefly extended on either side of the leaf.

Above, Feynman wrote about real electrons, not theoretical electrons. He described what the most common thinkable electrons do, say the electrons in the mains power socket, wherever and whenever in the World, Bottling Controls included.

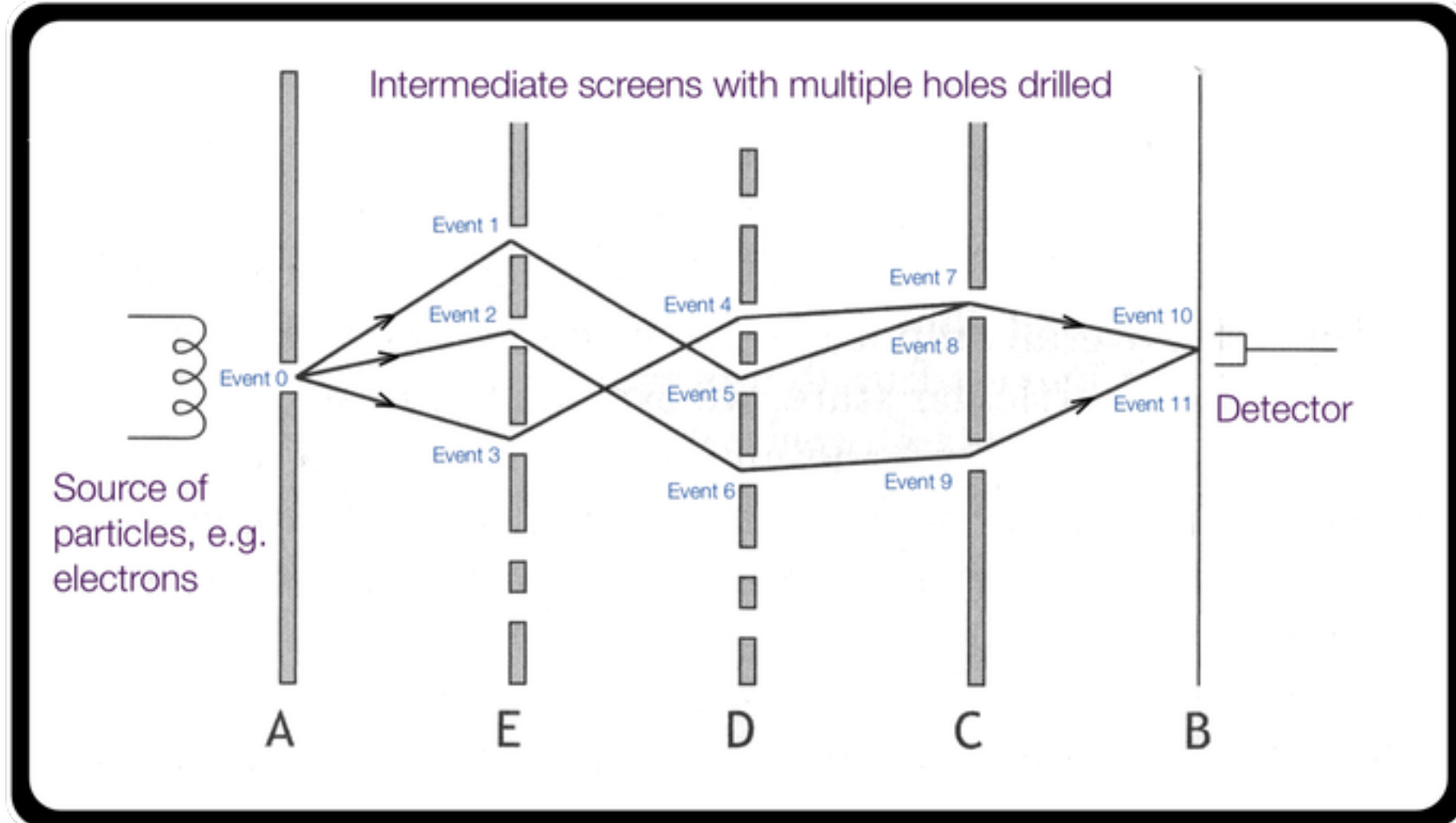
Dynamics starts to appear when and where sufficiently many such spread-out probability functions $\Psi_1, \dots \Psi_2, \dots \Psi_i, \dots \Psi_N$ are superposed, building up a localized wave packet, thus:

"Spacetime tells matter how to move; matter tells spacetime how to curve"

John Archibald Wheeler



▲ Richard P. Feynman understood in the last decades of his life that the multitudes of particles' paths he studied in 1948 were not alternative, rather multiple coexisting paths



[2] $\Psi = c_1 \Psi_1 + c_2 \Psi_2 + \dots + c_i \Psi_i + \dots + c_N \Psi_N$

Constructive interference occurs where the phases of the several individual waves superpose themselves and agree, a behaviour visible in the video here down. This video, filmed on a macroscopic fluid, displays accurately the general behaviour of matter, everywhere and whenever, on all scales of dimensions over Planck's length 10^{-35} meter.

"If you're doing an experiment, you should report everything that you think might make it invalid -not only what you think is right about it; other causes that could possibly explain your results; and things you thought of that you've eliminated by some other experiment, and how they worked- to make sure the other fellow can tell they have been eliminated"

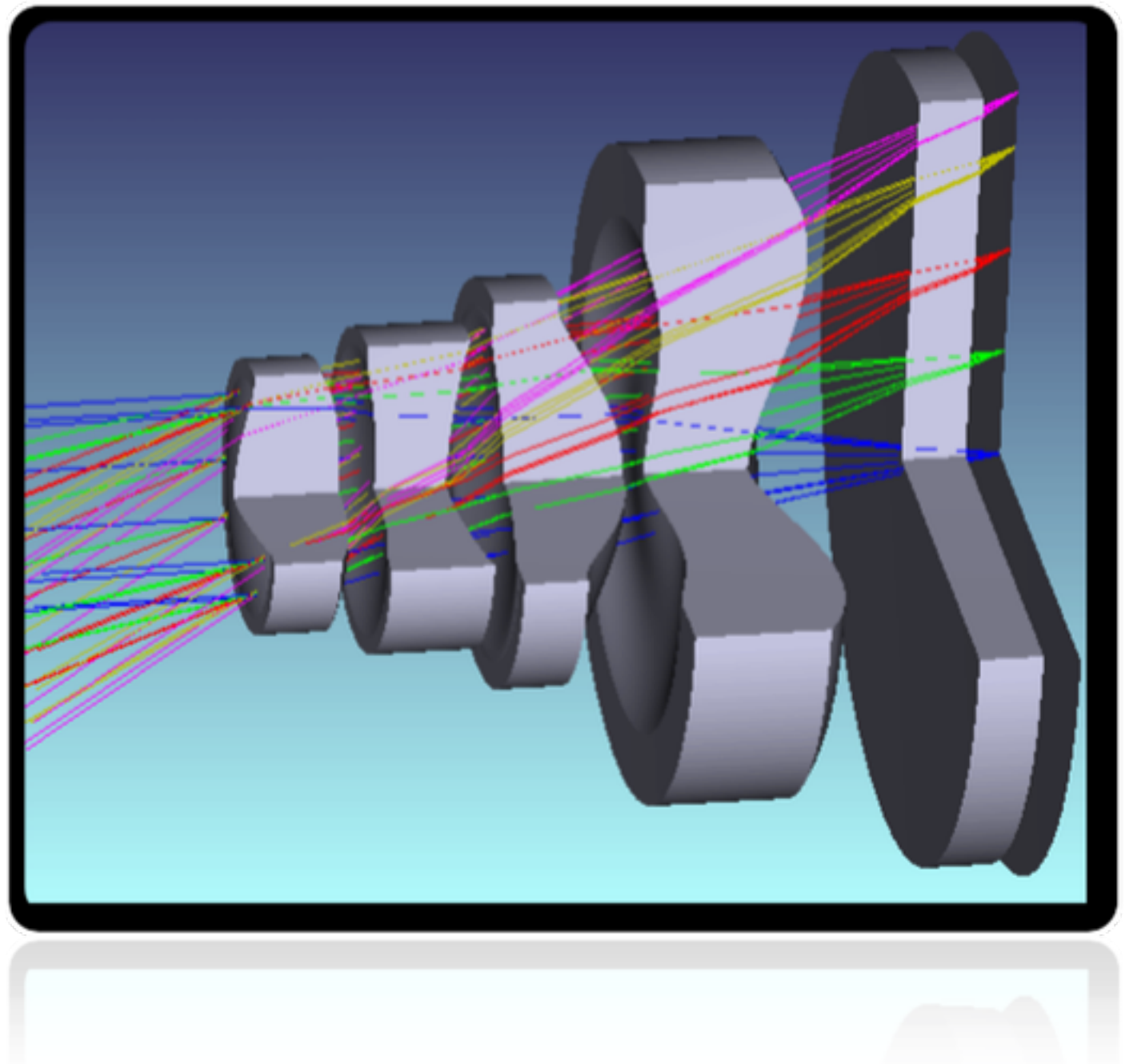
▲ Feynman about scientist's integrity (at Caltech, 1974)

Refer to the figure on right side, representing a multiplet with six optic elements in a smartphone. Feynman's point of view about the sum over histories encounters here an immediate application when trying to imagine the total of all of the superpositions involved in the formation of what we name *image*. Their number is mind boggling yet when trying to simplify the evaluation imagining each one lens of infinitesimal thickness, so to abstract by the diffraction and refraction effects between consecutive atoms in a lens. Their total grows further starting to consider that the majority of atoms, have plenty of substructures (e.g., quarks) which can individually interfere. We are trying to clear that when Nature is closely and thoroughly observed, it shows those numbers with hundredths of zeros which shall appear later in these pages.

On left side: the constructive and destructive superpositions of a multitude of terms [2] induce the familiar wave behaviour. This video, originating by macroscopic fluid parallel wave fronts advancing toward a couple of thin slits, illustrates with precision the behaviour of matter and radiation also at the subatomic scales. It is a

On right side: a 6-lenses optic multiplet in a common smart phone, illustrates superposition's complexity

case of interference of the waves deriving by the perturbations induced by two sources. Today it is clear they only exist waves and no “particles”. These last remained in common use as an approximation valuable because allows to simplify calculations in particular cases



To localize a particle, build a probability amplitude wave packet by superposing mono frequency terms:

$$\psi = c_1 \psi_1 + c_2 \psi_2 + \dots + c_i \psi_i + \dots + c_N \psi_N$$

Destructive interference takes place almost everywhere. The wave packet is concentrated in the region of constructive interference

packet is concentrated in the region of constructive interference
Destructive interference takes place almost everywhere. The wave

1982: the crossroad

John Bell's analysis and successive experiments demonstrated that the phenomenon named Entanglement, whose initial ideas are dated 1935, have to be part of reality rather than being the consequence of an incomplete description. Say, mere statistical correlations.

Single photon detectors, coincidence counters and powerful computers allowed a team of researchers of Sorbonne University led by Alain Aspect, a thorough statistical verification of the Entanglement phenomenon along the years 1980 to 1982. Quantum Mechanics, considering only two of its technological applications, namely Electronics and Information Technology, is yet the most successful scientific theory. In 1982, that part of the humanity knowing what is going to shape the future of whoever, understood it was reached an historical crossroad.

3 mutually excluding interpretations for the single meaning of *Reality*:

1. the limit speed of propagation of radiation is higher than light speed

(Bohm-De Broglie interpretation, 1952);

or:

2. Ψ represents a Quantum Field and multiple paths are actual

(Everett interpretation, 1957);

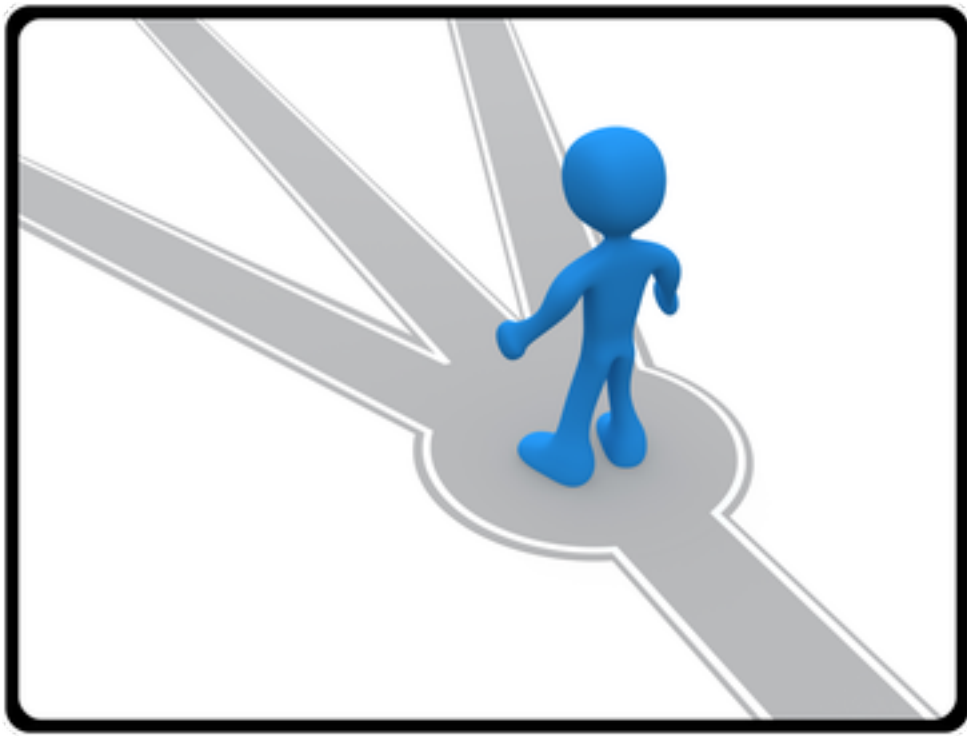
or:

3. an observation (or, measurement) is what let a physical status exists

(Bohr-Copenhagen interpretation, ~1932);

where the interpretation:

1. is contradicted by:
 - the generalized idea that causes exist and precede the effects;
 - Einstein's idea about the existence of a limit speed for light Signals. Special Relativity validity constantly reconfirmed by experiments on macroscales;
2. at first sight, seems Science Fiction;
3. is a solipsistic position, criticised by Einstein who observed he could not believe that a mouse could bring about drastic changes in the universe simply by looking at it.



After 1990, the new dominant fundamental theory of the nature, named String Theory, inter twined successfully the Relativity of 1915 with the Quantum Mechanics developed around 1926. Since then, the Event definition as detection of a packet of energy emitted (or, absorbed) by a source or process, is fully built over the cornerstone of those multiple coexisting Paths made of Events, but goes further. Today, after the Theory of Information revolution backed by theorems discovered in the last

decades whose impressive yield has only started to give its fruits, the Information is no more considered a *passive* element. Passive like a mere way to label properties and states of energy and matter. The concept of Event, its Information content and connections with other branches of the Science and Technology, are much broader today than they were in 1915. An Event is today, basically and in general, the name of the status of a physical or logical property. The entire line of reasoning based on the chaining of cause and effect, something which appeared obvious in 1915, one century later is object of deeper exams, and knowingly at odds with causal rooted ideas by experiments like those associated with Entanglement.

A key point regards the wave function Ψ which is what enters constantly in mathematical models related to the design of semiconductors. Exactly those accounting for > 99.9999 % of the components into CPUs and other Integrated Circuits. CPUs and Integrated Circuits which also allowed to increase the production speed of the World fastest Food and Beverage Bottling Line, from the ~9000 containers-per-hour of 1948 to the actual ~140000 containers-per-hour. There are plenty of practical and successful technological applications, like the Programmable Logic Controllers (PLCs, see figure on right side) and Frequency Converters into the Control Rooms of the Food and Beverage Bottling Lines, derived by the superposed waves building up the localized wave packet Ψ of the formula [2].



▲ **Alain Aspect, along 1980-1982, directed group of researchers who made the first decisive test of Entanglement and non-locality. experiments confirmed the non-local character of all, matter and radiation**

Triggered Event in the Third Millennium:

a paradigmatic change

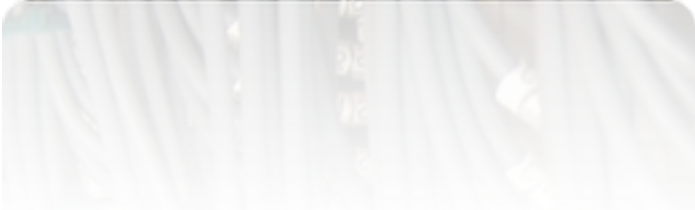
The Principle of Superposition. Classic version

All Engineers engaged on a daily base with Maintenance operations in the Machinery of Food and Beverage production Lines, remember they have applied several times and continue to apply an idea named Principle of Superposition. A canon some centuries old, always part of the design calculations of Electronics (Electronic Inspectors or Food and Beverage Bottling Controls, fully included), Mathematics and Analytical Mechanics.

The classic version of the Principle of Superposition, basically enounced in the form on right side, is based on the assumption that the system:

- 1. is linear (the function satisfies the conditions of additivity and continuity)
- 2. it is insulated by the Environment: no influence (or, inputs or, stimuli) on the system except the inputs considered (x and y , in the example on right side);
- 3. has no subsystems then: *no correlation of subsystems'* states.

Considering that the state of a system is uniquely defined by the correlations of its subsystems, the point 3. above could surely be a reasonable assumption centuries ago, when the Principle was born. Science and Technologies proceeded so much in the reduction of measurement uncertainties that yet in the year 1900, the evaluation by Planck of the constant since then carrying his name, implied an update of some assumptions valid since centuries. Without to enter in fine-details, we all know that yet the simplest linear systems, when closely looked are, in the reality, extremely complex.



▲ **Programmable Logic Controllers (PLC) and Frequency Converters are applications of the same Quantum Mechanics nonclassic rules in all Food and Beverage Bottling Lines. The Modern Principle of Superposition was modelled in 1957 over *complex automata*, today's name for PLCs**

Principle of Superposition, classic version

For all linear systems, the net response at a given place and time caused by two or more inputs (or, stimuli) is the sum of the responses which would have been caused by each input (or, stimulus) individually.

Then, if x , y are the inputs and a , b are two scalars, the correlated output is:

$$f(a x + b y) \Rightarrow a f(x) + b f(y)$$

Known examples: inductors and capacitors connected to alternate current generators, mechanical resonance of metal bars, waves, etc. The same term *complexity* hints to the existence of subsystems, and subsystems' states are correlated. In the reality, the supposedly *linear behaviour* was yet centuries ago object of the doubts and investigations of

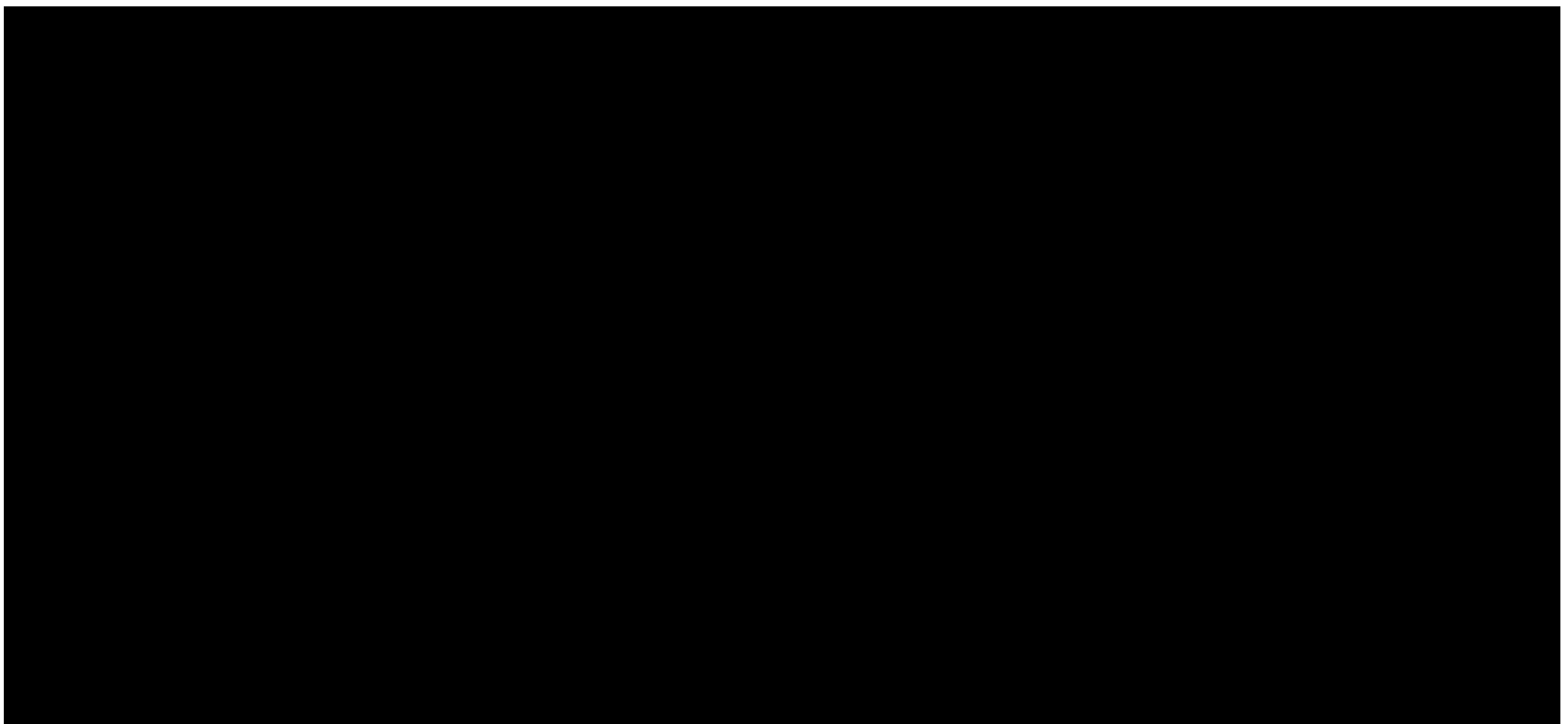


On left side: all clockworks are systems of linear mechanical components. Since centuries knowingly to be extremely sensible to the Environment. The entire Physics was tentatively modelled as a *clockwork world* until the year 1899, when the nobelist Max Planck makes the decisive breakthrough which changed the course of mankind history

many. Also the clockwork visible above is a known complex and purely mechanical system, where the Environment (e.g., the ambient Temperature and atmospheric pressure) is decisive, and different times shall be presented following different conditions.

Example 1

Superposition of two waves with the same wavelength



To understand how many ideas lies today back of the word *Superposition*, we suggest the vision of the 3-dimensional animation above. Its flip simulation involved more than 15 millions of points and ~3 millions of points are the visible foam. We suggest full screen, High Definition and a bandwidth adequate to the (impossible) task to perceive with less than 100 billion active neurons the simultaneous motion of millions of objects. The wave motion of liquids, visible in the animation, is a particularly complex case of what formulae show in the following. In the wave motion of liquids, undercurrent foam and spray are influenced by flip particle movement.

The Principle of Superposition in its classic version, when applied to two (or, more) waves with the same wavelength λ , ***superposed*** and propagating along the same direction, states that they can be considered as being a single wave whose instantaneous amplitude is the geometric sum V of the individual instantaneous amplitudes of the separate waves U and U' .

As an example, let us consider two monochromatic (isofrequential) waves U and U' with the same amplitude a , differing only for their phases, ϕ and ϕ' :

$$\begin{aligned} U &= a \cos (\omega t - \phi) \\ U' &= a \cos (\omega t - \phi') \end{aligned}$$

The instantaneous value of their combined amplitudes U and U' , is:

$$\begin{aligned} V &= U + U' = a [\cos (\omega t - \phi) + \cos (\omega t - \phi')] = \\ &= 2 a^2 \cos [(\phi - \phi')/2] \cos[\omega t - (\phi + \phi')/2] \end{aligned}$$

The new amplitude A depending upon the difference of optical paths x and x' of each wave, expressed in units of the wavelength λ , results:

$$A = 4 a^2 \cos^2 (\pi / \lambda) (n x n x') = 2 a^2 \{1 + \cos [2 n (x - x') / \lambda]\}$$

Thus, there can be both constructive and destructive interference between the two waves, and the resulting amplitude can be anything between 0 and 2a. This result is extremely important in that it is stating that the sum of two waves can be also be their mutual annihilation and disappearance. The precedent example, however complex it may appear, treated a case where the entire dynamical phenomena lies in a spatially limited volume: no external Environment is affecting the 4D evolution of the wave.

It is, literally, *infinetely* less complex than the one hinted by the video animation above.

Example 2

A supposedly linear system: RLC resonant serie circuit

An example of the strict correlation of the subsystems and of the correlation between a system and its Environment, is known to Electronic Engineers operating in Food and Beverage Bottling Lines. The RLC resonant circuit behaviour, when varying the frequency of the alternative current Signals applied. Inductors, resistors and capacitors are linear components, where *linear* means they are bipoles whose behaviour follows the classic version of the Principle of Superposition.

These circuits are defined by Maxwell's differential equation [3] where E is the potential, L the inductance, C the capacity, R the resistance, i the current, t the time, f the frequency and where $\omega = 2 \pi f$:

[3]

$$E \sin \omega t = L \frac{di}{dt} + Ri + \frac{1}{C} \int i dt$$

having solution [4] for the current intensity i :

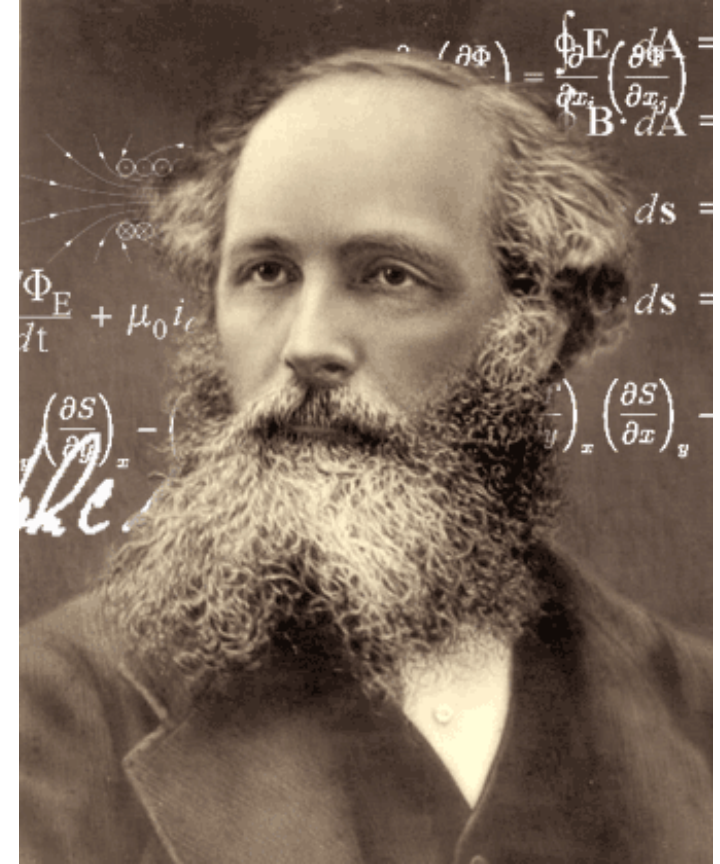
[4]

$$i = \frac{E}{\sqrt{R^2 + \left(\omega L - \frac{1}{\omega C}\right)^2}}$$

These relations between currents, voltages, resistance, inductance and capacitance are what we are expecting to see when applying the Principle of Superposition, assuming it fully applies to this kind of system and its subsystems.

Connect to a Signal or Functions Generator the RLC (Resistor-Inductor-Capacitor) serie circuit, creating what visible on right side and power on setting a sinusoidal wave form:

- ideally, to allow precise measurements, the behaviour of the circuit should be controlled by mean of an instruments to measure values of intensity of high frequency alternate current, with scales until 10 μ A, 100 μ A, 1 mA and 10 mA;
- if such an instrument is not available, to understand what happens may be enough a visual display of the wave form and its features:
 - directly in the Function Generator (like in the figure on side), or;
 - by mean of an Oscilloscope connected to the same leads where the Function Generator or Signal Generator is connected;
- start by a frequency of 50 Hz and increase the frequency by decadic steps to: 500 Hz, 5 kHz, 50 kHz, 500 kHz, 5 MHz, 50 MHz;
- after each increase of frequency:
 - observe and take a note about the intensity of the current (or, evaluate the oscilloscope's wave forms, if you have no microamperometer);
 - *move your hand* at a distance of 300 mm by the circuit, and look for effects on the measurements readouts (or, waveforms' shapes);
- for frequencies > 200 kHz the fact to oscillate the hand a few centimetres, by a distance of 300 mm, let a circuit built with three surely *linear* components behave an apparent *nonlinear* way. The hand, lying out of the RLC circuit visible on side, is now part of an *Environment* undoubtedly *correlated* with the resonant circuit;
- staying far from the circuit and increasing the value of the frequency, we are spectators of the circuit increasingly complex behaviour due to the superposition of the effects of distinct behaviours:
 1. RLC circuit resonance;
 2. correlations between RLC circuit's subsystems;
 3. correlation between the resistor R and Environment;
 4. correlation between the inductor L and Environment;
 5. correlation between the capacitor C and Environment;
- closing the entire circuit in a Faraday cage and increasing the value of the frequency, we are spectators of the circuit increasingly complex behaviour due to the superposition of the effects of distinct behaviours:
 1. RLC circuit resonance;
 2. correlations between RLC circuit's subsystems;
 3. correlation between the resistor R and Environment, where the superposed terms due to electromagnetic induction by the power network, motors, data, radio, TV, are minimised, but still they remain several other contributions;



▲ The formulæ on left side, so important for the design of Electrotechnics and Electronics circuits, are only two of the many discoveries with far reaching consequences in our lives we owe to the British physicist James Clerk Maxwell

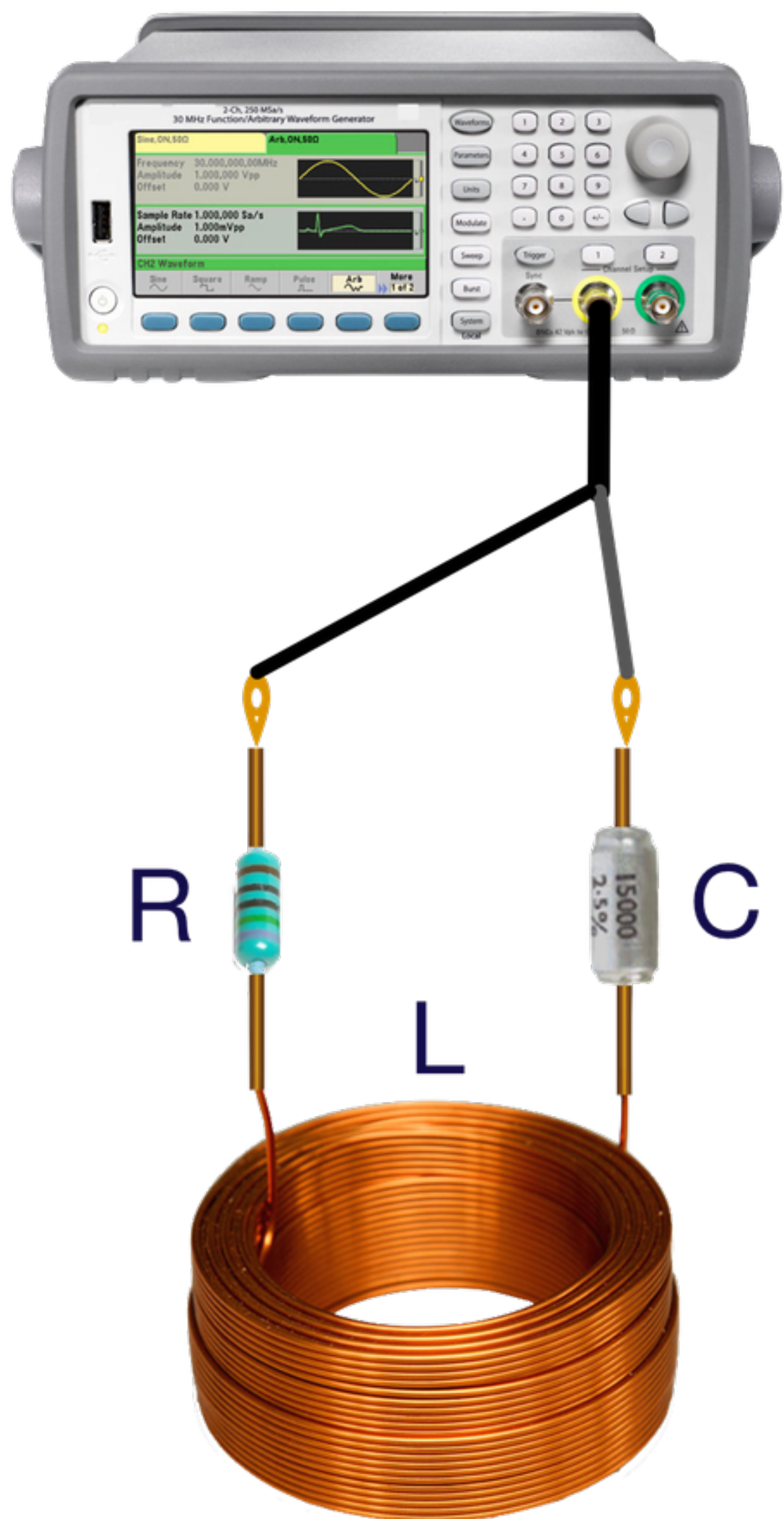
4. correlation between the inductor L and Environment, where the superposed terms due to electromagnetic induction by the power network, motors, data, radio, TV, are minimised, but still they remain several other contributions;
5. correlation between the capacitor C and Environment, where the superposed terms due to electromagnetic induction by the power network, motors, data, radio, TV, are minimised, but still they remain several other contributions;

implying a complex behaviour which the definition of the Principle of Superposition we are adopting like our Polar Star, does not appear fully capable to handle;

- increasing the frequency of the signal from 500 kHz to 50 MHz the circuit is markedly showing a complex behaviour. The RLC circuit expected operation is progressively replaced by a vectorial *superposition* of different effects:

◦ Resistor R

1. is progressively showing properties we'd expect by a superposed inductor because of the solenoidal geometry of its material and also because the couple of terminals are metallic, then themselves inductors;
2. a superposed capacitor, because of the potential existing between different sections;
3. skin effect is progressively increasing the impedance, reducing the section of its terminals really interested by the passage of electrons;
4. the metal oxides of which the resistor is made behave a different way, introducing unexpected superimposed effects;
5. changes in the Environmental temperature around the resistor, seems to be intervening in the operation, introducing unexpected superimposed effects;
6. there is an additional alternative current induced in the terminals and in the resistive metal oxides materials lying in the em field created by the Inductor;
7. there is an additional alternative current induced in the terminals and in the resistive metal oxides materials lying in the em field created by the terminals of the Capacitor C;
8. there are additional alternative currents induced in the Resistor, originating by the fact that the Generator is not ideal (it radiates);
9. there are additional alternative currents induced in the Resistor, due to sudden fluctuations in frequency, polarization and amplitude of the electromagnetic fields in the Environment (e.g., data, radio and TV transmissions, cables of power network radiating at 50 or 60 Hz);
10. there are additional alternative currents induced in the Resistor, impulses of brief duration due to cosmic rays;
11. there are additional alternative currents induced in the Resistor, impulses of brief duration due to environmental radioactivity;
12. the electromagnetic fields of prior point 9. also fluctuate because of sudden changes in the local value g of the Earth gravitational field, when no way exists to shield gravitationally the RLC circuit and gravimeters' measurements' repetition rate < 10 Hz, always delayed with respect to the



▲ **The fiction. Linear character of the inductor, resistor and capacitor is what we expect to see after connecting them to Functions or Signal Generator in a RLC serie circuit, powered by a sinusoidal wave form. Linear means they are bipoles whose behaviour follows the classic version of the Principle of Superposition**

em induced interfering signals we'd like to compensate;

13. (.....).

o **Capacitor C**

1. shows a progressively marked behaviour equivalent to the one we'd expect by an inductor, because its terminals are metallic;
2. an additional parallel capacitor, because of the potential existing between its terminal;
3. skin effect is progressively increasing the impedance, reducing the section of its terminals interested by the passage of electrons;
4. the dielectric behaves a different way, introducing unexpected superimposed effects;
5. changes in the Environmental temperature around the capacitor, seems to be intervening in the operation, introducing unexpected superimposed effects;
6. there is an additional alternative current induced in the terminals and in the metal plates, lying in the em field created by the Inductor L;
7. there is an additional alternative current induced in the terminals and in the metal plates lying in the em field created by the passage of current thru the terminals of the Resistor R;
8. there are additional alternative currents induced in the Capacitor, originating by the fact that the Generator is not ideal (it radiates);
9. there are additional alternative currents induced in the Capacitor, due to sudden fluctuations in frequency, polarization and amplitude of the electromagnetic fields in the Environment (e.g., data, radio and TV transmissions, cables of power network radiating at 50 or 60 Hz);
10. there are additional alternative currents induced in the Capacitor, impulses of brief duration due to environmental radioactivity;
11. there are additional alternative currents induced in the Capacitor, impulses of brief duration due to cosmic rays;
12. the electromagnetic fields of prior point 9. also fluctuate because of sudden changes in the local value g of the Earth gravitational field, when no way exists to shield gravitationally the RLC circuit and gravimeters' measurements' repetition rate < 10 Hz, always delayed with respect to the em induced interfering signals we'd like to compensate;
13. (.....).

Down: the reality. RLC are correlated subsystems and each one of them separately and differentially exposed to an Environment whose relation with the correlated RLC is impossible to fully account

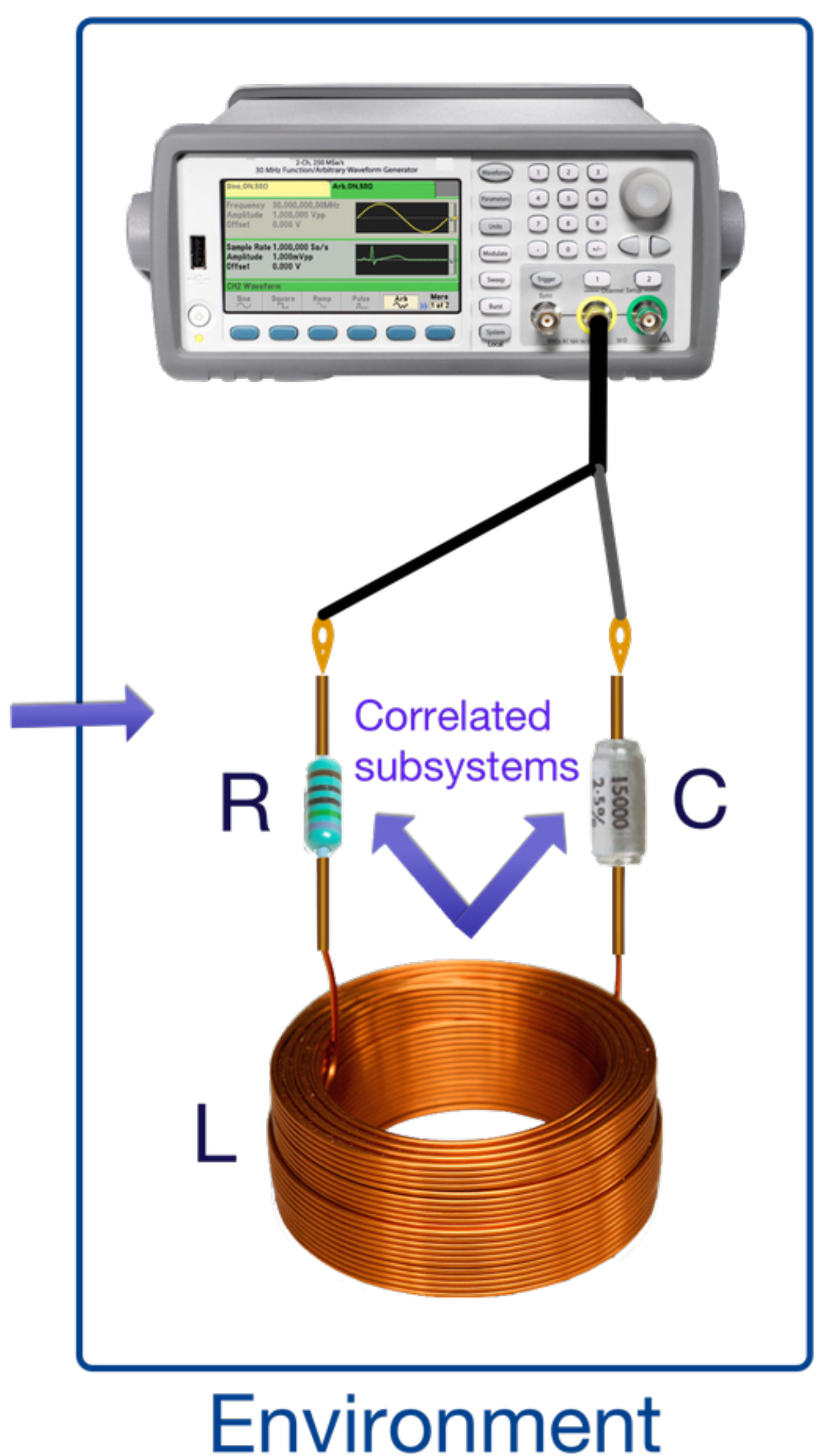
o **Inductor L**

1. is progressively showing properties we'd expect by a superposed capacitor, because of the fact that its resistance is not zero and then a potential exists between different sections of the solenoid;
2. an additional parallel capacitor, because of the potential existing between its terminals;
3. skin effect is progressively increasing the impedance, reducing the section interested by the passage of electrons;
4. the air in which the winding lies, is clearly intervening in the operation, following relatively small changes in the Environmental humidity, introducing unexpected superimposed effects;
5. there is an additional alternative current self-induced in the terminals and in the solenoid, lying in the em field created by the same Inductor L;
6. there is an additional alternative current induced in the terminals and in the solenoid lying in the em field created by the passage of current thru the terminals of the Capacitor C;
7. there is an additional alternative current induced in the terminals and in the solenoid lying in the em field created by the passage of current thru the terminals of the Resistor R;
8. there is an additional parasitic capacitance originating by the fact that the winding has not zero resistance and that there is a dielectric in between them;
9. there are additional alternative currents induced in the Inductor, originating by the fact that the Generator is not ideal (it radiates);
10. there are additional alternative currents induced in the Inductor, due to sudden fluctuations in frequency, polarization and amplitude of the electromagnetic fields in the Environment (e.g., data, radio and TV transmissions, cables of power network radiating at 50 or 60 Hz);
11. there are additional alternative currents induced in the Inductor, impulses of brief duration due to environmental radioactivity;
12. there are additional alternative currents induced in the Inductor, impulses of brief duration due to cosmic rays;
13. the electromagnetic fields of prior point 10. also fluctuate because of sudden changes in the local value g of the Earth

gravitational field, when no way exists to shield gravitationally the RLC circuit and gravimeters' measurements' repetition rate < 10 Hz, always delayed with respect to the em induced interfering signals we'd like to compensate;

14. (.....).

The values we registered for the current i , so different than what expected by the equation [4] have shown that the impedance characteristics of common circuit elements (resistors, capacitors, inductors) utilized in circuit theory, are simply low-frequency asymptotes of the overall frequency responses of these components. Also, these tests show that each one of the three components, yet when took separately by the others violates the rules for a linear device because has internal subsystems and, worse, subsystems whose behaviour with respect to the frequency is differential. This, means that also the three circuits on right side, equivalent to Resistor, Capacitor and Inductor yet when separately considered, are frequency-dependant. Their aspect and performances change, following the frequency. Also, these equivalent circuits abstract by the existence of the Environment. Comparing the reality we discovered, with fourteen elementary components appearing below rather than three (R, L, C), it becomes easier to imagine why the observed behaviour is so complex and divergent by what the differential equation [3] defines.



On right side: equivalent circuits of a single Resistor, Capacitor and Inductor. The values we registered for the current i , so different than what expected by the equation [4], shows that the impedance characteristics of common circuit linear elements R, L, C, are only low-frequency asymptotes of the overall frequency responses of these components

Up to 750 GHz

Imagine now to have the possibility to access a Signal Generator capable to reach an even higher frequency, e.g. 750 GHz. Then, the only model explaining what is observed is that one where the amount of superposed and correlated effects diverges to infinity.

When fronted by the necessary answers to the following questions we start to feel much more than the superposed effects of the multitude of particles building up an atom of Copper in a conductor:

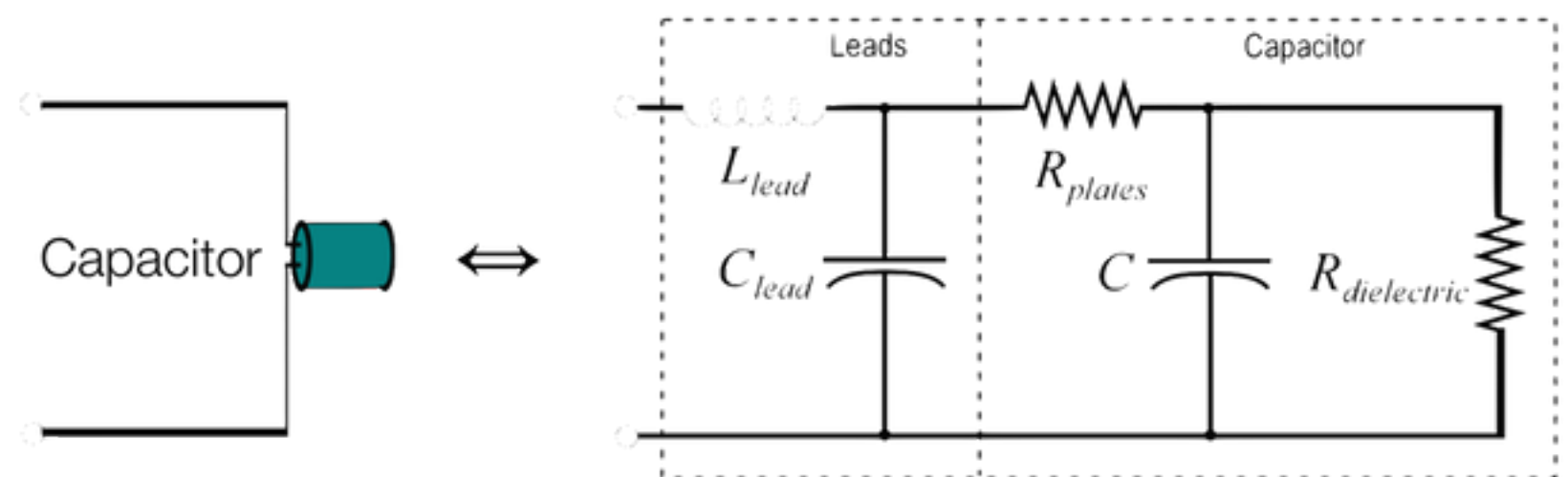
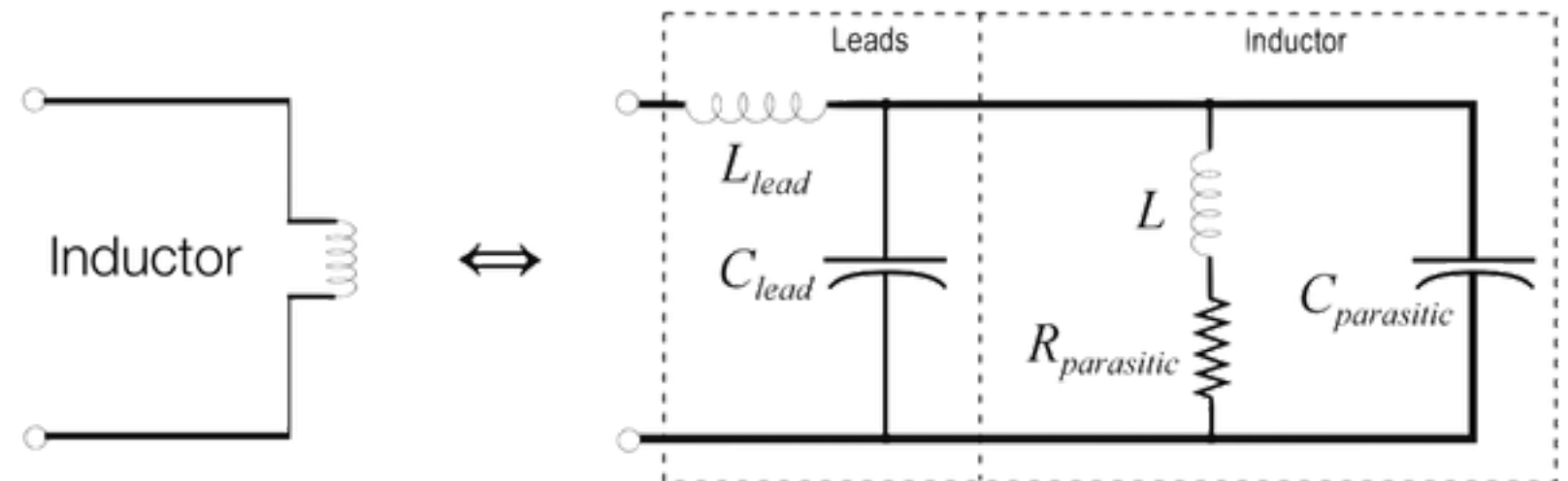
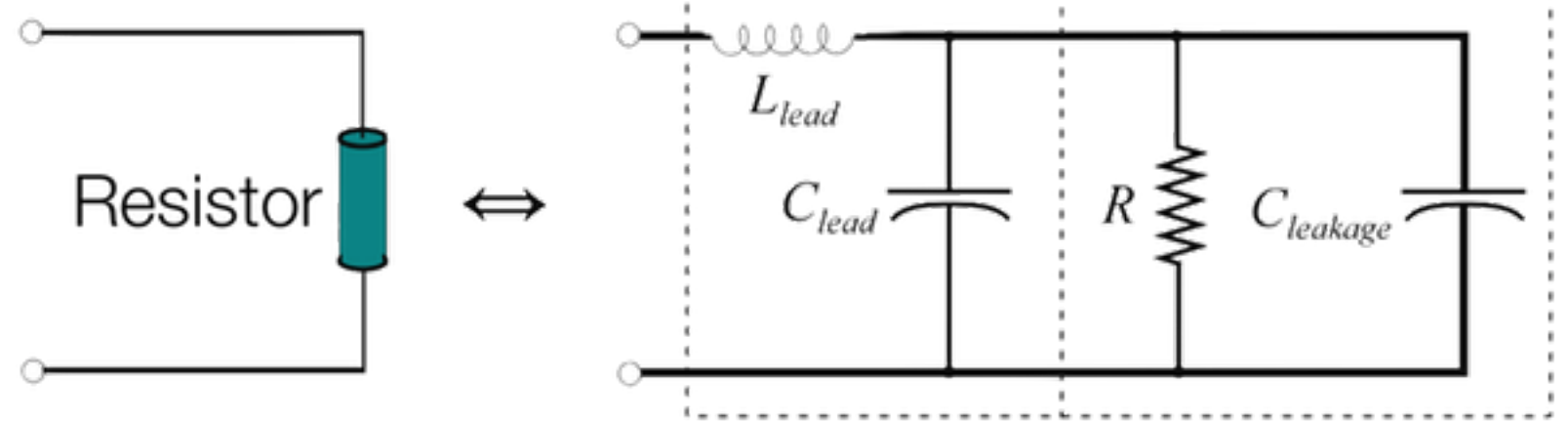
1. what of the effects, and in what amount, is due respectively to the RLC circuit and to the Environment ?
2. of the space-time existing around the circuit, what section to consider *Environment* ?
3. of all of the objects (e.g., elementary particles, atoms, molecules, macroscopic bodies) existing in the section of space-time we have chosen to consider *Environment*, what and in what extent to consider causally connected ?
4. for each one infinitesimal frequency in such a wide range, we'd be forced to deduce the complete detailed behaviour by the measurement of an amount of properties which, having been forced to include the Environment, is now no more limited to three RLC components, rather extended to a mind boggling amount;
5. the measurements instruments we are using are not *ideal*, and the amplitudes of their uncertainties, as we increase the Signal frequency and extend to the Environment the exam, becomes of the same size as what we are looking as *Signals*. What to consider Signal and what to consider a fluctuation due to the instrument uncertainty ?
6. what should happen when increasing the frequency toward infinite ?
7. how to treat the chained effects of a change in the temperature T implying a new value for the resistance R, inductance L and capacity C ? ...say the equation to the partial derivatives:

$$\partial f(R, L, C) / \partial T$$



▲ Nonlinear classic devices were born long before transistors.

Legacy vacuum tubes are non-linear devices, operating on base of Electrostatic. A portion of their characteristic curve shows the equivalent of a differential negative resistance, what made of them the first Signal amplifiers of the history



The “paradox” is only a conflict between reality and your feeling of what reality “ought to be.”

Richard P. Feynman



Introducing the module below in the out feed of a Signal Generator like the one above, it becomes possible to extend until 750 GHz the frequency of the signals introduced into electrical and electronic circuits. Thus, allowing to witness the divergence of the super posed correlated effects. An infinity converging to a limited however mind boggling amount due to the discretization of the frequencies readable in the Generator (abridged by images credited above to Rohde & Schwarz®, and Virginia Diodes® below)



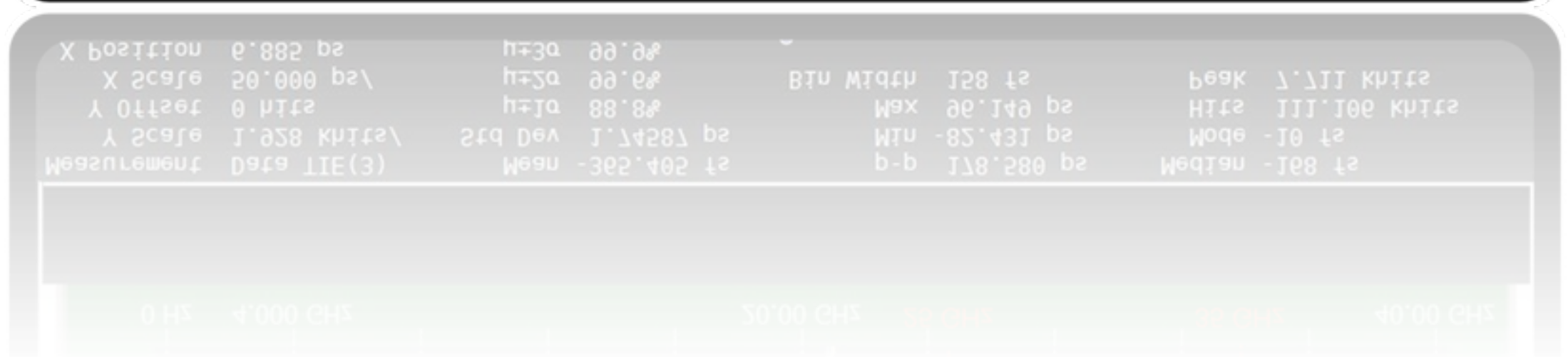
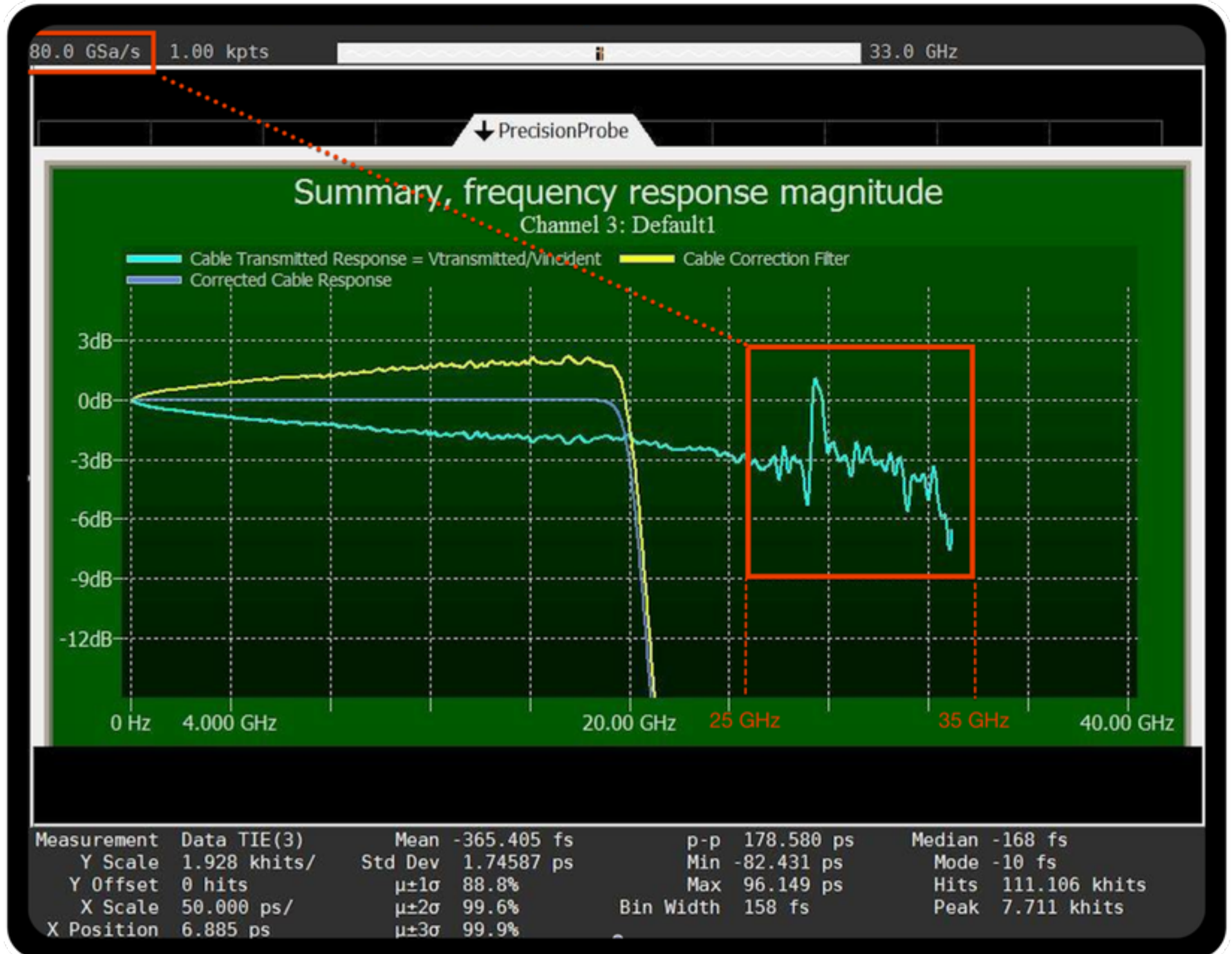
We saw above only a small fraction of all of the aspects that an allegedly-simple RLC serie circuit presents when closely examined by mean of the Principle of Superposition, into its Environment and increasing the frequency of the alternative current i . Above we considered a relatively complex case with three electronic components. May linearity be assured when considering simpler examples ? Of all of the electrical components, no one is simpler than a cable. What above is true also for the less suspect of the linear devices, like the common copper cables and their connectors, visible in the figure on right side. Also cables, linear when transferring DC power (not closely looking what in the meantime is going on in the atomic scale) start to reveal their true nonlinear nature, as much as we increase

the frequency of the Signals. How true this statement is can be inferred by the graphics below.

Here shown a cable powered in a range of frequencies: (0 - 34) GHz. In the vertical axe, the relation between transmitted and incident signals, expressed in dB. The cable transmitted response (voltage trasmitted / voltage incident) quite finely evaluated sampling the signals 80 billions of times per second. In the figure, evidenced by a red colour square, the oscillating behaviour shown over signals' frequencies of 27 GHz. A classically unexpected behaviour, manifestly complex and nonlinear. We leave the Reader imagine what it may signifies, in terms of deviations, to power that same cable at 750 GHz, considering that yet at 30 GHz the frequency response is what visible in the graphics below.



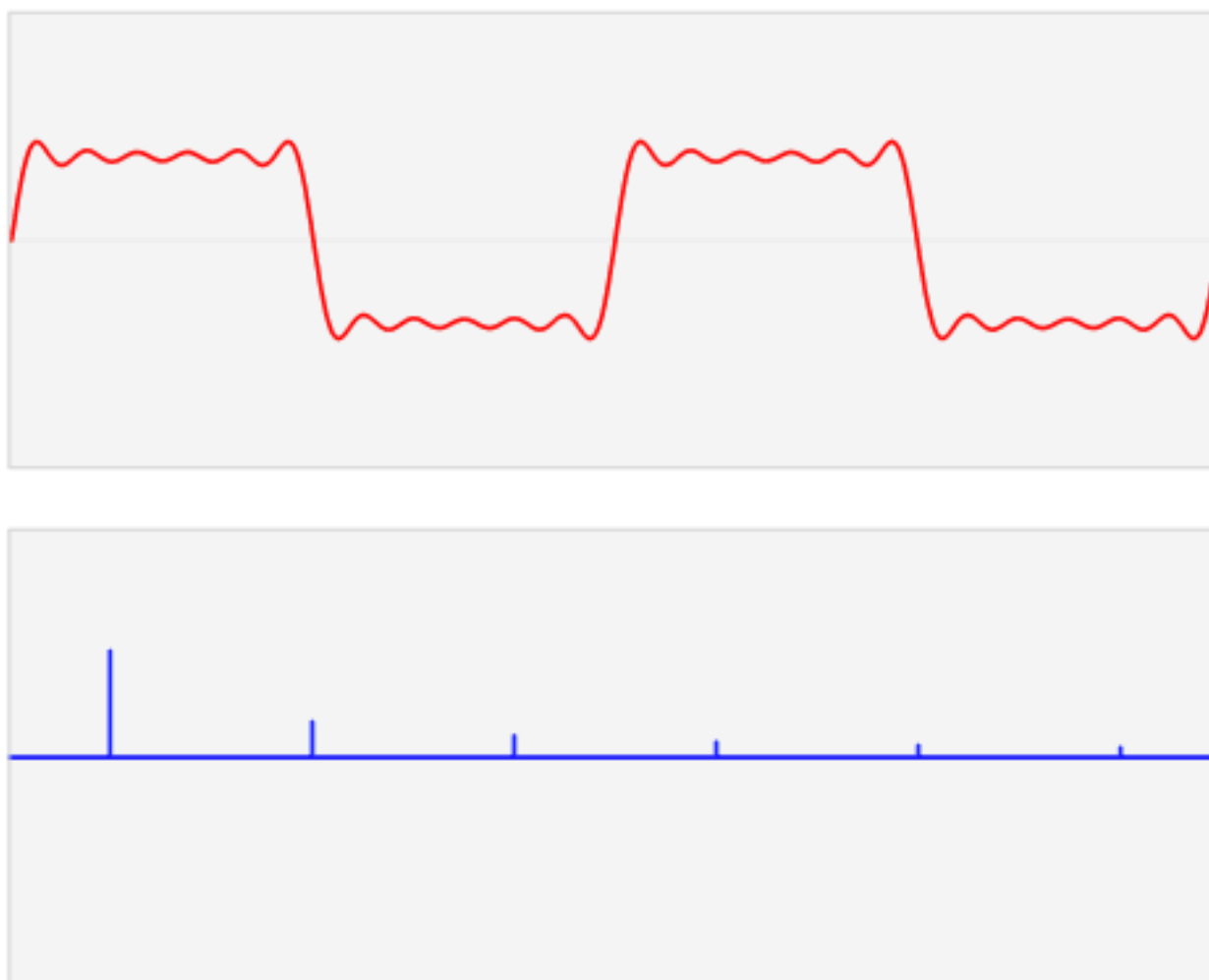
▲ Also cables, *linear* when transferring DC power, and not closely measuring what in the meantime is going on their atomic scale, start to reveal their nonlinear nature as much as we increase the Signals' frequency



▲ A classically unexpected behaviour manifestly nonlinear of the simplest electric components. It shows itself when increasing the signals' frequency. In the example referred to a cable, to signals' frequencies ranging (27 - 34) GHz correspond wide deviations out of what expected by classical Electrodynamics. Nature has an *agenda* different than our classic, itself based on a completely different set of assumptions. In evidence the fact that the standard deviation (Std Dev) of the timing is only 1.74587 ps (picoseconds, say 10^{-12} s). We are here with great precision closely looking the Events

Example 3.

Superposition and decomposition of 6 waves



▲ Fourier transformation converts all *amplitude given time* functions in *amplitude given frequency* functions. The example shows how six sine waves alternatively superimpose themselves to form a single function and how the function decompose itself in the six superposed terms (image credit L. V. Barbosa, 2013)

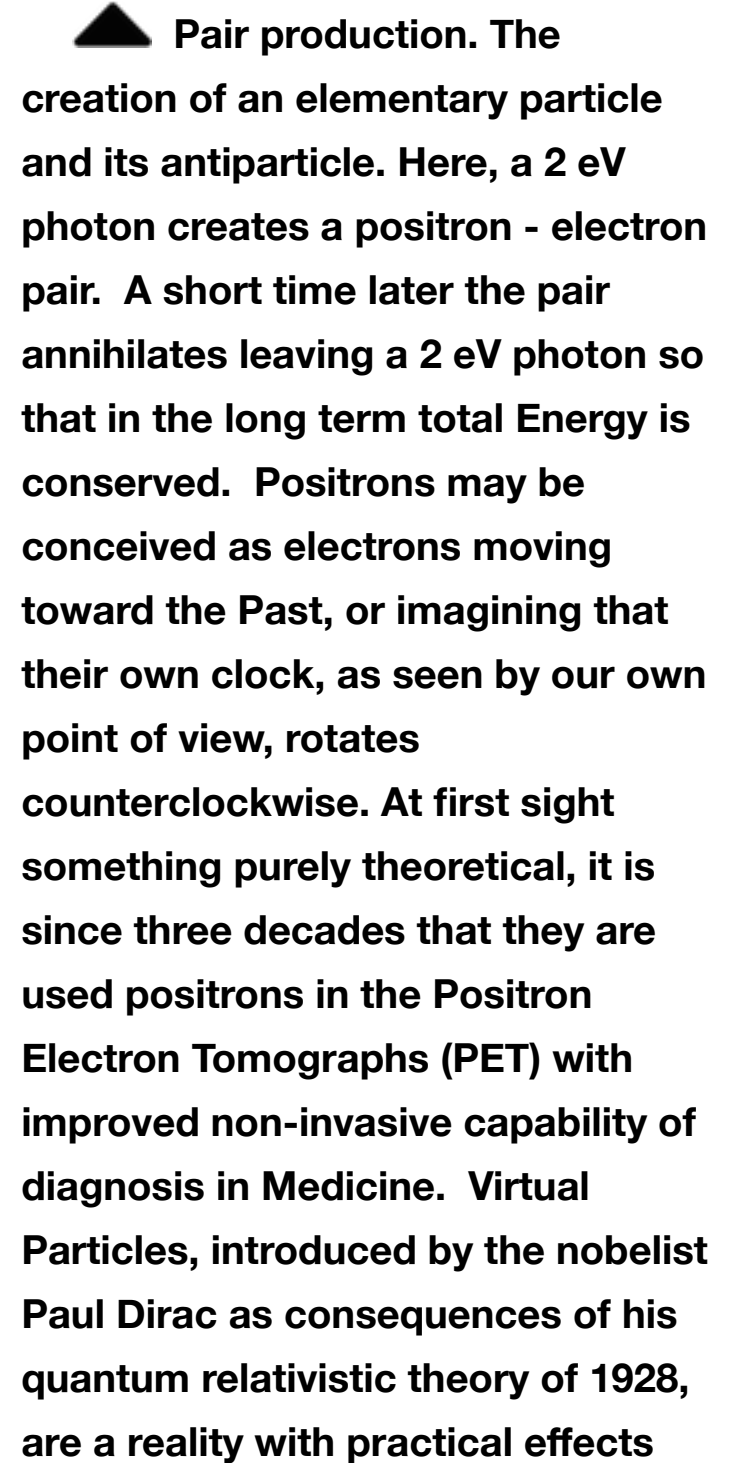
Long time due questions about the Information Flow underlying measurements

Since more than seven decades it is known that our measurement instruments (RLC circuit included) and Machinery are causally related with other ($10^{78} - 10^{82}$) particles. Particles close enough to allow the establishment of a causal relation.

Two fundamental questions questions:

1. *Where is the Intelligence necessary to coordinate, on such distances and at such infinitesimal levels of precision, all these atoms ?*
 - **Never detected: it does not exists.** Since centuries it had been abandoned the antropic idea that natural facts correspond to the manifestation of an intelligence. Then, Nature has to apply a different mechanism to create that sensation of Physical Laws used, as an example, to design everything technological. A different definition for Superposition, one allowing to have however ready the correct answer, the fitting eigenvalue, also in absence of an intelligence to precalculate and transmit the correct. The next question 2. and answers, strictly related to this, is what is considered the mechanism allowing the coordination.
2. *Where is the Information Flow underlying such coordination ?*
 - **Virtual Particles play the role.** In the following, an abridged list of cases and technological applications whose existence is assured by Virtual Particles, in the framework of the Quantum Field Theory:
 1. **Electromagnetic induction.** This phenomenon transferring energy to and from a magnetic coil via an electromagnetic field can be viewed as a *near-field effect* (see point 12). It is the basis for power transfer in transformers, electric generators and

2. **Coulomb force between electric charges.** It is caused by the exchange of virtual photons. In symmetric 3-dimensional space this exchange results in the inverse square law for electric force. Since the photon has no mass, the Coulomb potential has an infinite range.
3. **Magnetic field between magnetic dipoles.** It is caused by the exchange of virtual photons. In symmetric 3-dimensional space this exchange results in the inverse cube law for magnetic force. Since the photon has no mass, the magnetic potential has an infinite range.
4. **Hawking radiation**, where the gravitational field is so strong that it causes the spontaneous production of photon pairs and particle pairs.
5. **Strong nuclear force**, between quarks is the result of interaction of virtual gluons. The residual of this force outside of quark triplets (neutron and proton) holds neutrons and protons together in nuclei, and is due to virtual mesons such as the pi meson and rho meson.
6. **Weak nuclear force.** It is the result of exchange by virtual W and Z bosons.
7. **Decay of an excited atom**, accompanied by spontaneous emission of a photon. Such a decay is prohibited by ordinary Quantum Mechanics and requires the quantization of the electromagnetic field for its explanation.
8. **Casimir effect**, where the ground state of the quantized electromagnetic field causes attraction between a pair of electrically neutral metal plates.
9. **Van der Waals force**, which is partly due to the Casimir effect between two atoms.
10. **Lamb shift** of positions of atomic levels.
11. **Vacuum polarization**, which involves pair production or the decay of the vacuum, which is the spontaneous production of particle-antiparticle pairs.
12. **Electromagnetic near-field.** Where the magnetic and electric effects of the changing current in the antenna wire and the charge effects of the wire's capacitive charge may be important contributors to the total em field close to the source, but both of which effects are dipole effects that decay with increasing distance from the antenna much more quickly than do the influence of conventional electromagnetic waves that are far from the source. Far-field waves, for which \mathbf{E} is (in the limit of long distance) equal to $c \mathbf{B}$, are composed of *actual photons*. It should be noted that *actual* and *virtual photons* are mixed near an antenna, with the virtual photons responsible only for the extra magnetic-inductive and transient electric-dipole effects, which cause any imbalance between \mathbf{E} and $c \mathbf{B}$. As distance from the antenna grows, the near-field effects (as dipole fields) damp themselves more rapidly, and only the "radiative" effects that are due to actual photons remain as important effects. Although virtual effects extend to infinity, they drop off in field strength as r^2 rather than the field of electromagnetic waves composed of actual photons, which drop $1/r$. The powers respectively decrease as $1/r^4$ and $1/r^2$

[illegible]

▲ since decades is known that each one material particle had time to causally connect with all $\sim 10^{80}$ others lying in the common tetradimensional volume, within the boundary named Hubble-horizon. Following the classic clockwork World conception, the Information Flow necessary to let such an amount of objects continuously coordinate their physical properties (positions, energies, polarizations, etc.) to follow Physical Laws, should have to be impressive. But was never detected, implying that Nature adopts another solution: Virtual Particles

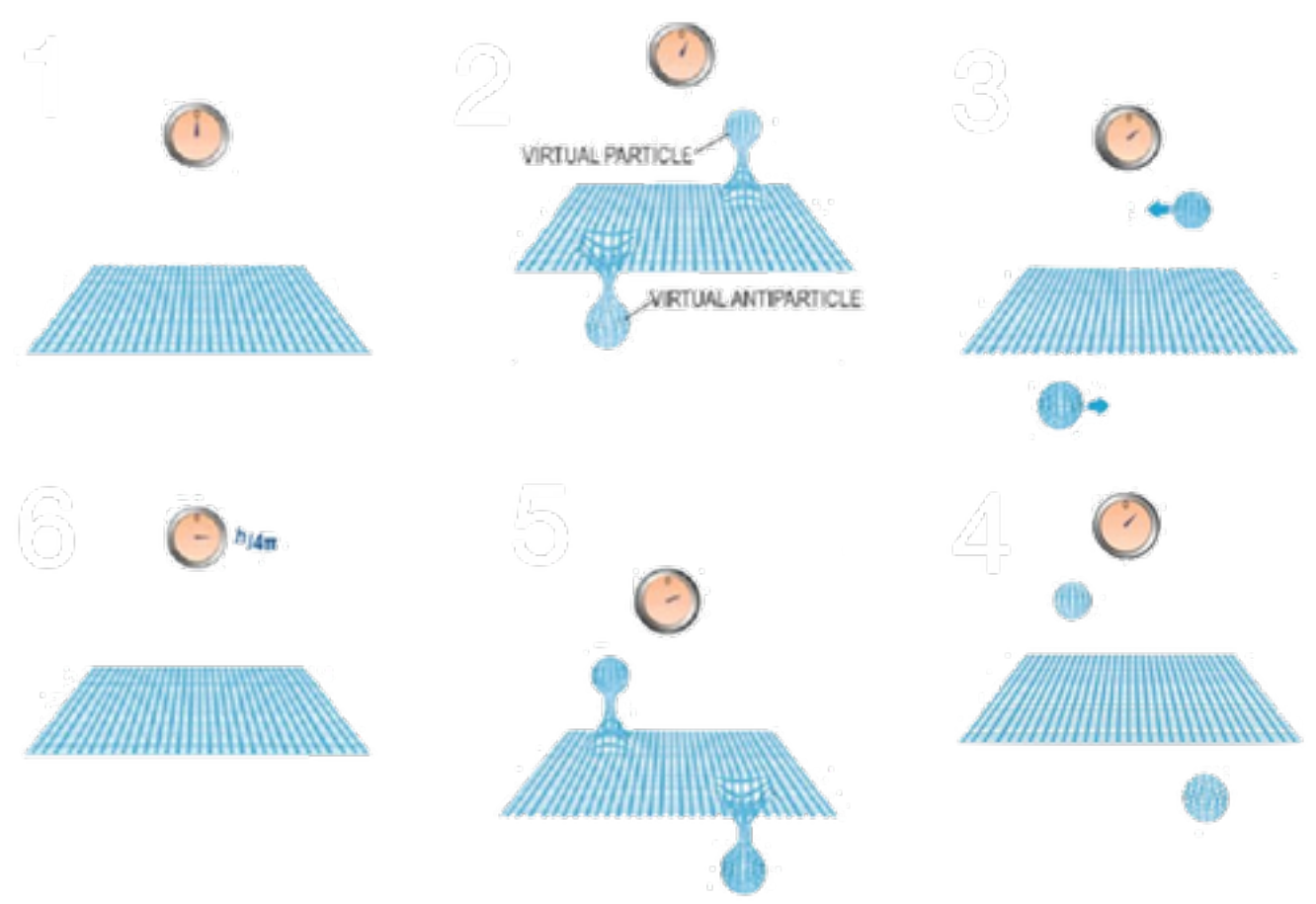
Why the classic version of the Principle of Superposition fails

What precedes demonstrates that the majority of the linear systems encountered are simplifications of a nonlinear reality, under some basic assumptions which, in the case of electronic circuits, can be synthesized as:

- 1. no Environment;
- 2. no high frequency Signals;
- 3. no Virtual Particles;
- 4. full linearity of the eventual subsystems of the linear system, in our case, the RLC circuitry;
- 5. no correlations between the eventual subsystems of the linear system, in our case, the RLC circuitry.

The intrinsic nonlinearity in these conditions is not perceptible in those measurements which are accessible to direct observation, because in them the nonlinear terms are quite negligible in comparison with the linear ones.

On right side: six stages in the evolution of a Virtual Particle and of its counterpart traveling backward in time. The Classic Principle of Superposition, still today taught in the high schools and colleges, was coined centuries ago when electromagnetic and coulombian forces' effects were considered fully accounted. Since 1928 the description agreeing with what in the experiments *pops-out to existence* are Paul Dirac's *Virtual Particles*



That's why the Classic version of the Principle of Superposition is found to be confirmed. Surely, the Classic Principle of Superposition presents the advantage to have to solve relatively simple algebraic or (linear) differential equations, rather than much more difficult nonlinear differential equations. But, can this way to proceed let our knowledge advance toward the solution of intrinsically nonlinear problems ? Ignoring Virtual Particles' existence, when these are assuring electro magnetic and coulombian forces is an ill-fated position. Then, only the dissipative effects of active power (watt) in the resistor R, are truly accounted by the Classic Principle of Superposition.

"No impedance, no reactive nor apparent powers due to the Inductor or the Capacitor or the

No impedance, no reactive nor apparent powers (famously measured VAR and VA) due to the Inductor or the Capacitor or the inductance and capacity of a real Resistor, can be explained without Virtual Particles, say without the Quantum Field Theory (QFT). The denomination "Virtual Particles", comprehensible when it was coined several decades ago, results today a bit inappropriate. The Virtual Particles are not less real than all other *Particles*. Since decades the technological progress is allowing to observe them in experiments made in the widest range of ambient temperatures, comprised between a little more than the absolute zero and billions of Kelvin degrees. They were *new physics* ...seventy years ago !

The transition from classic to quantum

The classic physics “state"

In classical physics, the notion of the “state” of a physical system is intuitive. It is focused on certain measurable quantities of interest, for example, the position and momentum of a moving body, and subsequently assign mathematical symbols to these quantities (such as “x” and “p”). The state of motion of a body is then specified by assigning numerical values to these symbols. In other words, there exists a one-to-one correspondence between the physical properties of the object and their mathematical representation in the theory. To be sure, we may certainly think of some cases in classical physics where this direct correspondence is not always established as easily as in the example of Newtonian mechanics used here. As an example, it is rather difficult to relate the formal definition of temperature in the theory of Thermodynamics to the underlying molecular processes leading to the physical notion of temperature. However, reference to other physical quantities and phenomena usually allowed one to resolve this identification problem at least at some level.

The quantum physics “state"

The one-to-one correspondence between the physical world and its mathematical representation in the theory came to an end with quantum theory after 1926. Instead of describing the state of a physical system by means of intuitive symbols that corresponded directly to the “objectively existing” physical properties of our experience, in quantum mechanics we have only an abstract quantum state that is defined as a vector (or, more generally, as a ray) in a similarly abstract Hilbert vector space. The conceptual leap associated with this abstraction cannot be underestimated.

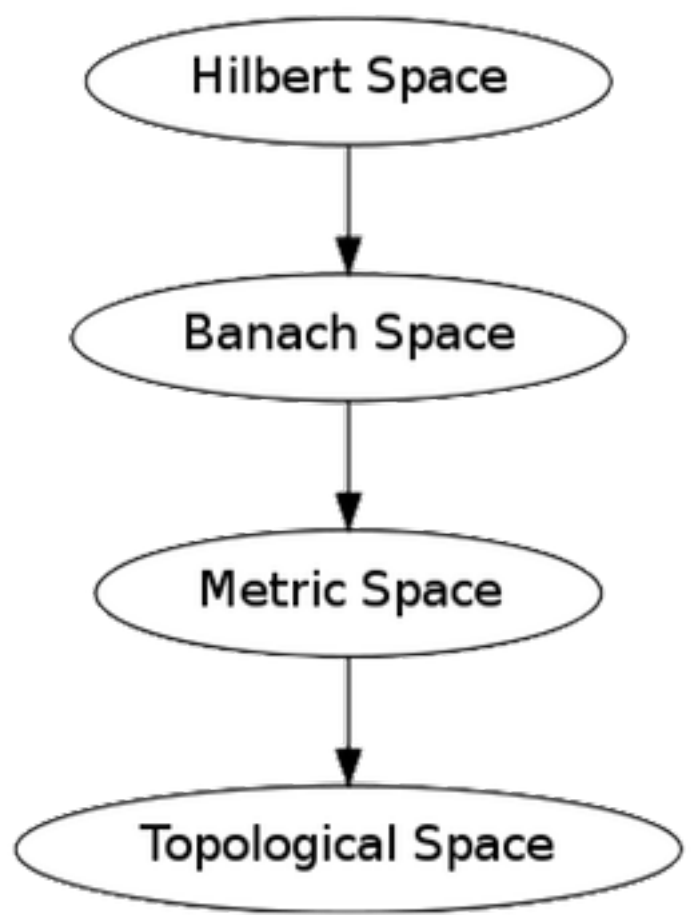
As a matter of fact, the discussions regarding the interpretation of quantum mechanics since the early years of quantum theory, are to a large extent due to the question of:

...how to relate the abstract quantum state to the physical reality out there ?

The connection with the familiar physical quantities of our experience is only indirect, through measurements of physical quantities, that is, of observables object of our measurements and everyday life, represented by (Hermitian) operators in a Hilbert space.

To a certain extent, the measurement allows us to revert to a one-to-one correspondence between the mathematical formalism and the “objectively existing physical properties” of the system, say to the concept familiar from classical physics. But, due to the fact that many observables are mutually incompatible (non commutativity), a quantum state will in general be a simultaneous eigenstate of only a very small set of operator-observables. Accordingly, we may ascribe only a limited number of definite physical properties to a quantum system, and additional measurements will in general alter the state of the system unless, we measure, by

inductance and capacity of a real Resistor, can be explained without Virtual Particles, say without the Quantum Field Theory (QFT)"



▲ **Relation between Hilbert space and Topological spaces. Topological spaces are defined by the most basic Set Theory**

virtue of luck or prior knowledge, an operator-observable with an eigenstate that happens to coincide with the quantum state of the system before the measurement. A consequence is that it is impossible to uniquely determine an unknown quantum state of an individual system by means of measurements performed on that system only. This situation is in contrast with classical physics. Here we can enlarge our “catalog” of physical properties of the system by performing an arbitrary number of measurements of additional physical quantities. Furthermore, many independent observers may carry out such measurements (and agree on the results) without running into any risk of disturbing the state of the system, even though they may have been initially completely ignorant about this state. The idea of preexistence of the classical states is a mere remnant of the limited knowledge we had along past centuries.

Actual or potential ?

In view of the properties of quantum states introduced above, it has often been argued that these states represent only *potentialities* for the various observed *classical* states.

At the same time quantum states:

- represent a complete description of a quantum system, encapsulating all there is to say about the physical state of the system;
- do not tell us which particular outcome will be obtained in a measurement but only the probabilities of the various possible outcomes.

This intrinsic probabilistic character of quantum mechanics, only thirty years ago taught as a canon, is only seemingly existing and, rather, an effect of our cultural perspective. In an experimental situation, the probabilistic aspect is represented by the fact that, if we measure the same physical quantity on a collection of systems all prepared in exactly the same quantum state, we will in general obtain a set of different outcomes. What had been fully understood along past decades, marrying the best experimental techniques to the most powerful theoretical ideas, is that **all possible measurement values, say all statuses, are actual.**

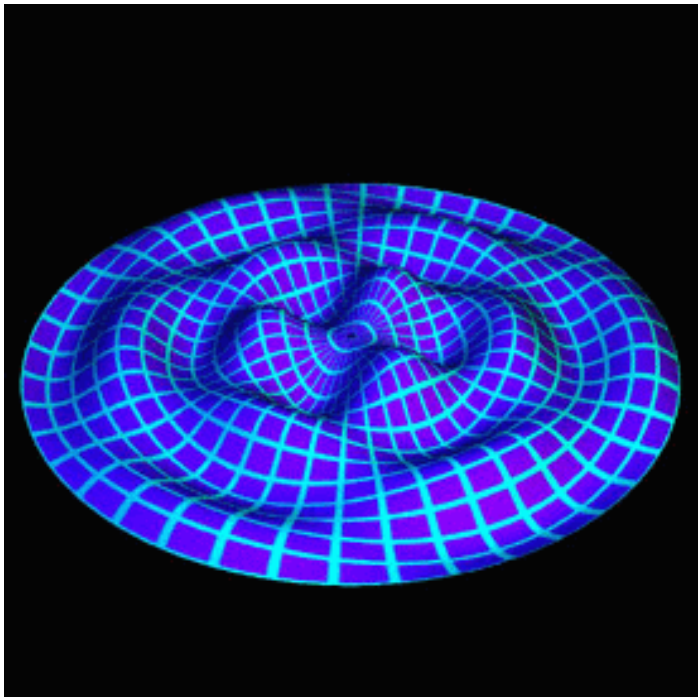
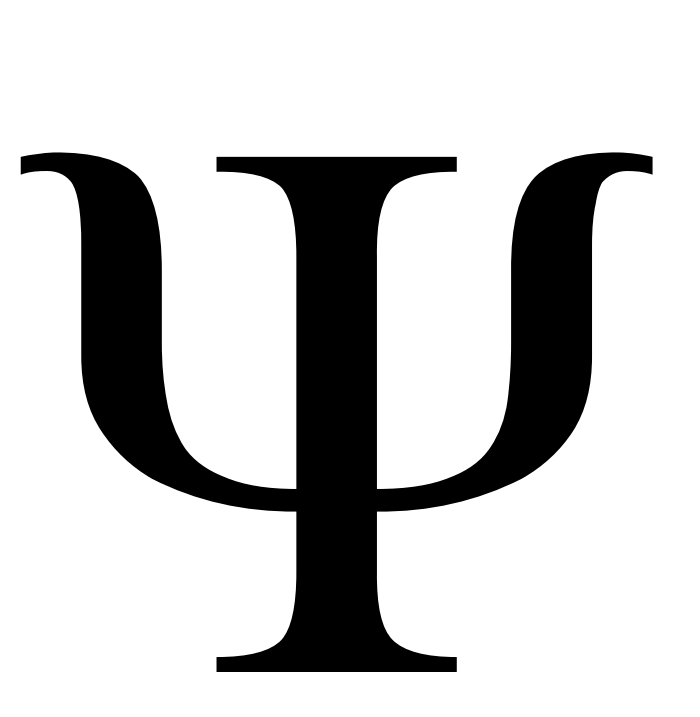
Schroedinger. Only waves

Reading textbooks written sixty years ago, you’ll be surprised by the difficulty to figure the named *wave-particle duality*. This idea, stood between those which delayed many initial efforts to understand Quantum Mechanics. The following decades demonstrated it was one more effect of the past cultural perspective.

Yet Erwin Schroedinger, the physicist depicted in the figure here on right side, in the early days of Quantum Mechanics when attempting to identify narrow wave packets in real space with actual physical particles observed two problems:

- initially localized wave packets spread out very rapidly over large regions of space, a behaviour irreconcilable with the idea of particles, by definition localized in space;
- the Wave Function Ψ describing the quantum state of $N > 1$ particles in the 3-dimensional space, resides in a 3N-dimensional Hilbert space. No more in the familiar 3-dimensional space of our experience.

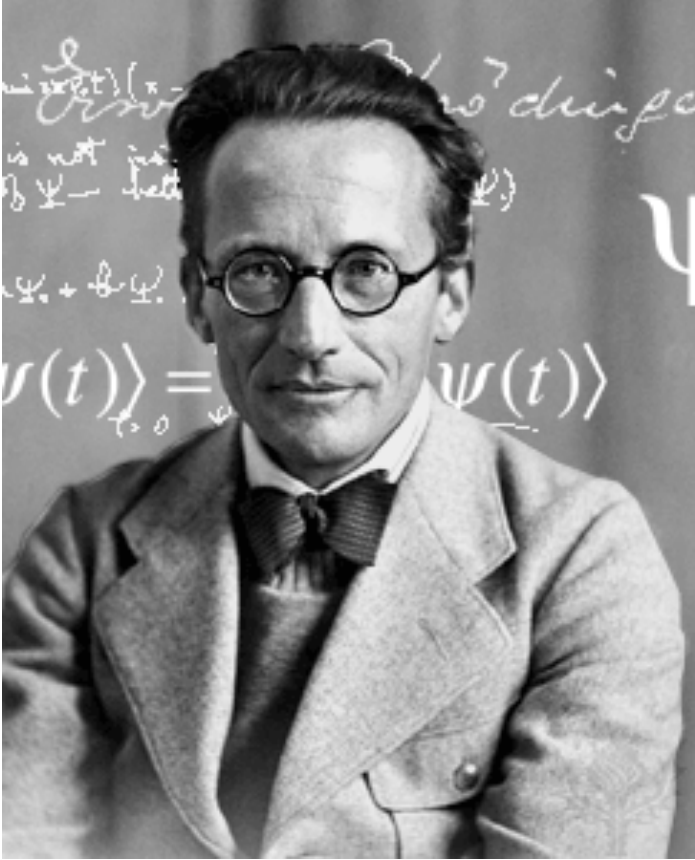
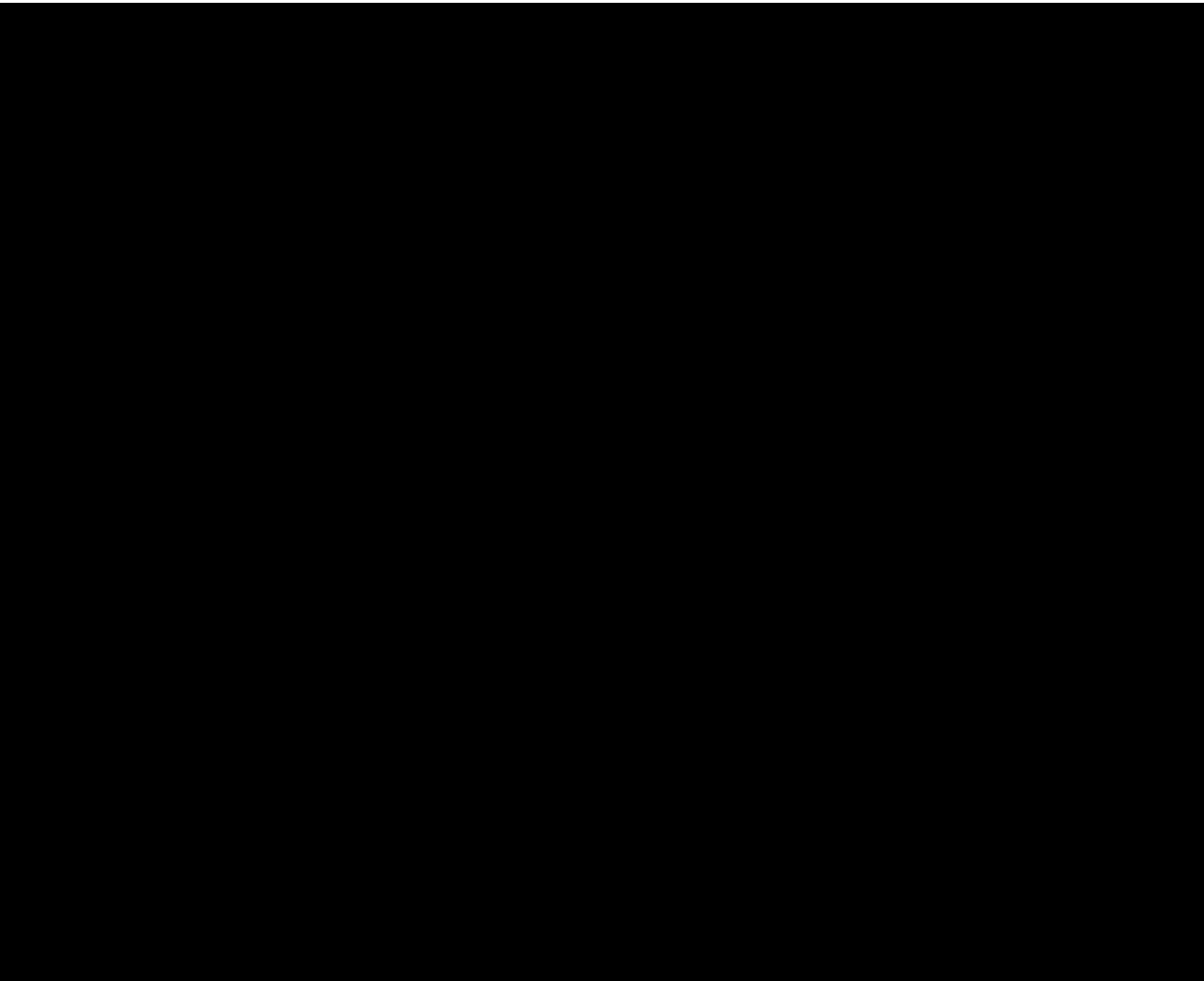
Particles are mere idealisations for a wave packet with relatively limited extension in the space-time. **They only exist waves.**



▲ Oscillation characteristic values (eigenvalues) are modes of vibration, each one oscillating its own frequency in this image of a drumhead (image credit J. Kreso, 1998-2010)

Objects and measurements' hidden nature:

constructive interference



▲ Erwin Schroedinger, probably the main founder of Quantum Mechanics. He was the first to understand that a multitude of simultaneous instances of the electron the Hydrogen proton, were modelled by his newly created Wave Function Ψ

▲ The first 6 modes of vibration of a standing wave on a string fixed at both ends, illustrates the concept of constructive interference (abridged by Adjwilley)

A further step implies to recognise what the 4-dimensional space, described by Minkowski and Einstein in the start of these pages, represents something real but abiding by the (derived, not fundamental) idea of Time. In other terms, around fifty years ago it has been understood that **the spacetime of 1915 does not exist**. The idea received contributions by many, between them Dirac, Bergmann, Pirani, Higgs, Arnowitt, Deser, DeWitt, Misner and Wheeler. The geometric dynamical reality it presents is referred to space with only 3 dimensions. What exists is a space whose dimensionality is at least 4, then superior to the 3 we are *biologically equipped to perceive* and not only mathematically conceive. It is named using a Latin language prefix Superspace S or, today more frequently by mean of a Greek language prefix, hyperspace.

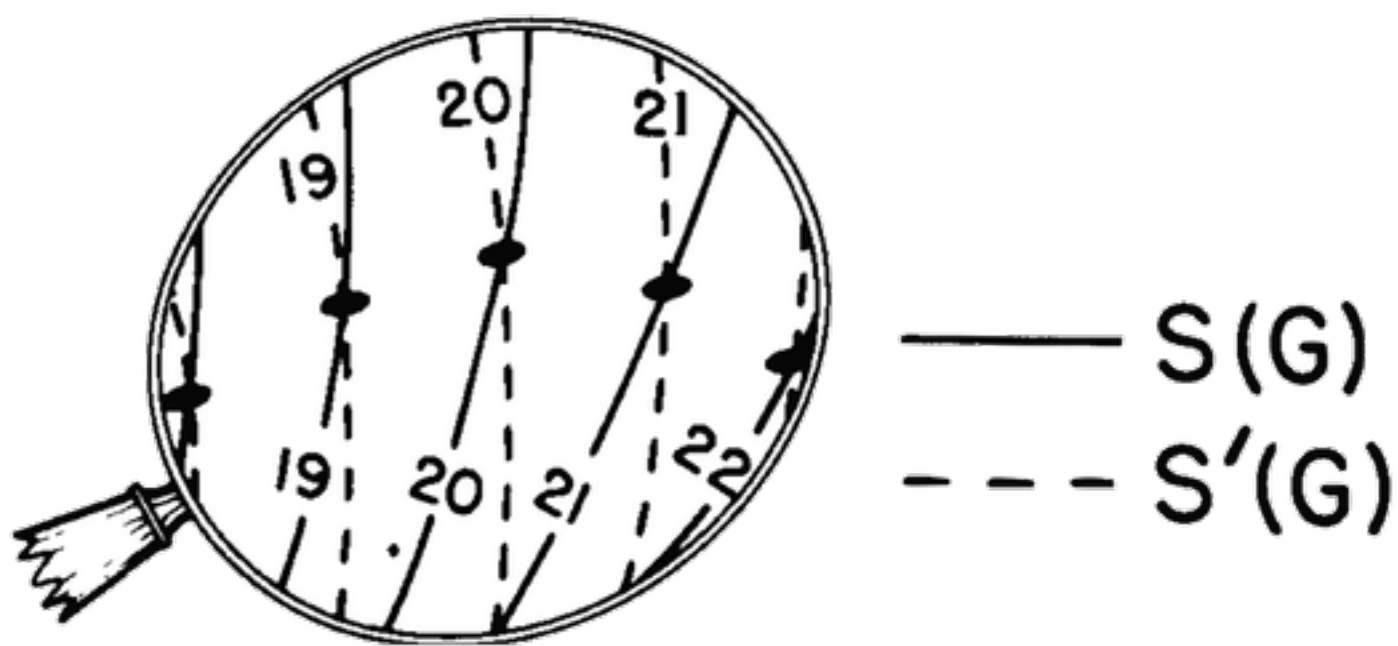
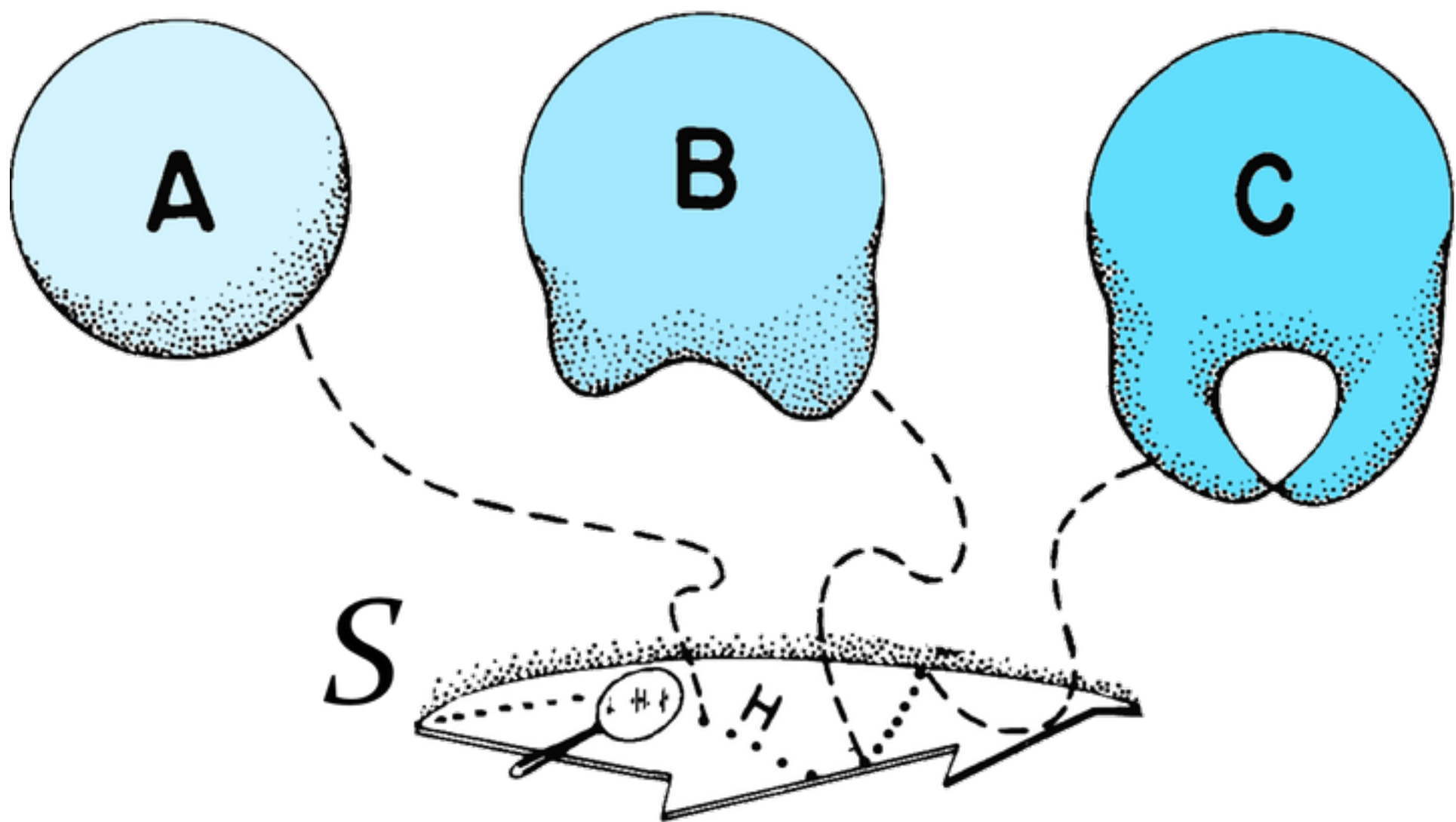
With reference to the figure below, the hyperspace S is the manifold each of whose 'points' A, B, C, ... represents all of the infinite points in a 3-dimensional space:

- smooth lines numbered 19, 20, 21, 22 are wave crests of probability amplitude function $\Psi_E(x, t)$, where E is the Energy, x a spatial coordinate and t the time parameter;
- dashed lines, same as before for an energy $E + \Delta E$;
- S(G) and S'(G) are the Hamilton-Jacobi dynamical phases due to different waves. Their elliptic intersection points, magnified by the lens, regions of constructive interference.

“An oscillating drop of water undergoes fission. The topology changes. A point marks the place of separation of the two masses of liquid. That point lacks the full neighborhood of points that characterizes a normal point. Such a critical point is ruled out from any proper manifold by the very definition of the term manifold in mathematics. Before the division, the surface of the drop constituted a manifold. After the division, it is again a manifold, consisting of two disparate pieces. At the instant of division it is not a manifold. But little attention does the drop pay to this distinction. It

divides, despite all definitions. No more reason does one see in the definition of manifold against space changing its topology”
John Archibald Wheeler, 1967

The submanifold H of S is the classical history experienced by the geometry of that 3-dimensional space, when space has been started off under some particular set of dynamical initial conditions. An entire 3-dimensional space, stands at an halfway position between a true mathematical point and what a *point* represents in the hyperspace.



▲ Imagine to have a lens powerful enough to magnify details $< 10^{-30}$ cm. In this realm, it becomes possible to see space true nature. Hyperspace S (also named, superspace) is the manifold each of whose *points* A, B, C, ... represents the infinite amount of points existing in a 3-dimensional space. Smooth lines numbered 19, 20, 21, 22 are wave crests of probability amplitude function $\Psi_E(x, t)$, where E is the Energy, x and t are a spatial coordinate and t the time parameter. Dashed lines, the same for an energy $E + \Delta E$. $S(G)$ and $S'(G)$ are the Hamilton-Jacobi dynamical phases due to different waves, their elliptic intersection points being regions of constructive interference, what we normally name *particles*. The submanifold H of S is the classical history experienced by the geometry of that 3-D space, when space has been started off under some particular set of dynamical initial conditions

In particular, a temporary configuration of:

- a particle is an Event, a single point in the spacetime;
- space is a 3-dimensional geometry, a single point in the hyperspace.

An arbitrary metric space A is defined to be *positive definite* if each of its finite subsets is positive definite with their induced metrics. 3-dimensional spaces have positive definite metric, **what implies that physical effects cannot propagate from one point of the 3-D geometry to another.** Why ? Because a physical quantity local to a point, and another local to another point, have no reciprocal coupling: they commute. The meaning of the sentence above in bold characters has far reaching consequences. It implies that also the appearances of material objects, a macroscopic case of the measurements (and, triggerings) of the Electronic Inspectors, are exclusively *happening between different 3-geometries* where we, our Electronic Inspection devices and machinery, are existing. The first clear idea of this by Minkowski, dated 1908, was valid only for flat, ideal, non existing Euclidean spaces. In 1967, these concepts were carried further by J. A. Wheeler, then the greatest living Relativist. He was capable to establish a firm bridge between the two most successful physical theories, General Relativity and Quantum Mechanics.

“all possible measurement values, say all statuses, are actual”

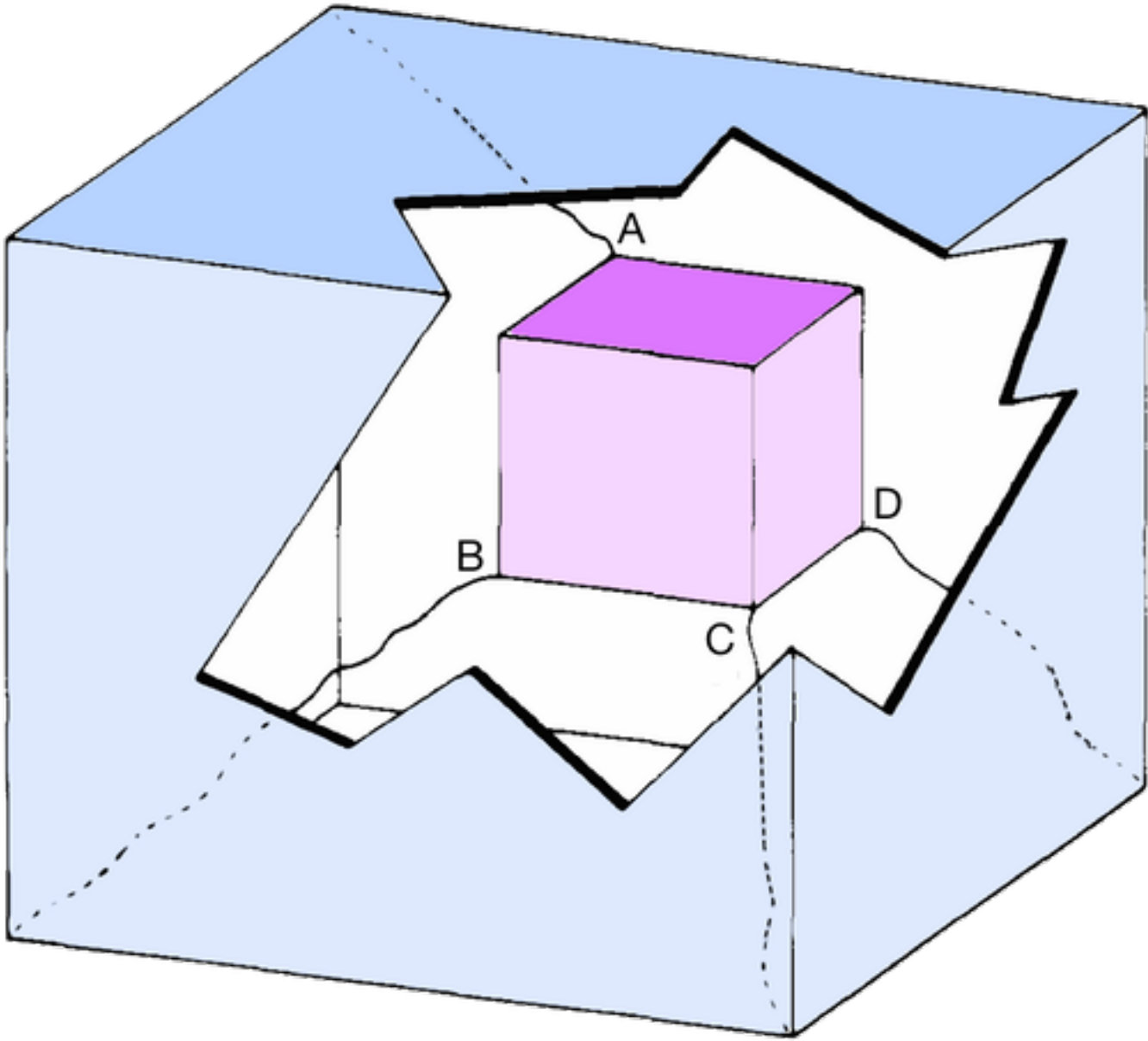
Topology-Spinors connection

There is a criteria to identify a topologic variety as a good candidate to be the master plan of the physical space. The same effects we observe on macroscopic objects or that we can logically infer, have to be autonomously rendered by that topology. Imagine a cube. Attached, like in the figure on right side, to four of its corners four elasting strings. Now, select any axis running through the center of the cube and rotate the figure about that axis through 360°. You'll see the cube returning to the original configuration, but not the strings. Strings shall be entangled and no way to untangle them. The 360° rotation alters the orientation entanglement relation between the cube and its surroundings. Two successive rotations by 360° restore the original orientation of the cube. Strings can now be untangled. The spinor is a mathematical operator accounting for the effects of these rotations with respect to the origin of a triad of coordinate axis. Until now we spoke only of the rotation of a cube and its surroundings.

Now, try to figure out what happens when the cube is slowly rotated through 360° when passing along the entire space of other geometric surroundings. As an example, a closed loop, or ring or an handle, or wormhole.

You'll discover that, under the same identical rotation of 360°, different 3-dimensional closed manifolds can be fully classified by total four properties:

- 1. topology;
- 2. differential structure;
- 3. metric;
- 4. **spin structure.**



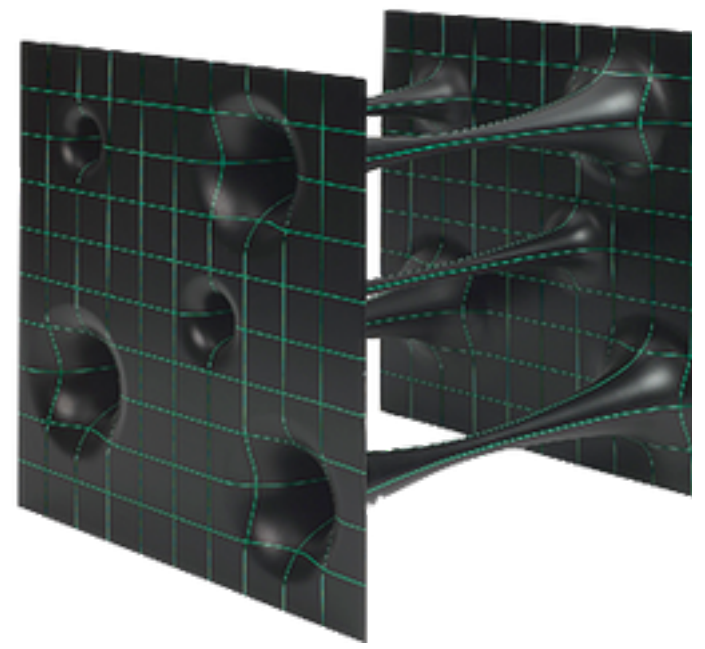
▲ **Imagine a cube. Attached to four of its corners four elasting strings. Select any axis running through the center of the cube and rotate the figure about that axis through 360°. The cube shall returns to the original configuration but not the strings. Strings shall be entangled and no way to untangle them. The 360° rotation alters the orientation entanglement relation between the cube and its surroundings (abridged by image credit J. A. Wheeler et al., 1973)**

The figure below, represents different kinds of 3-dimensional *points*. All of them are closed 3-dimensional geometries but some of them, like:

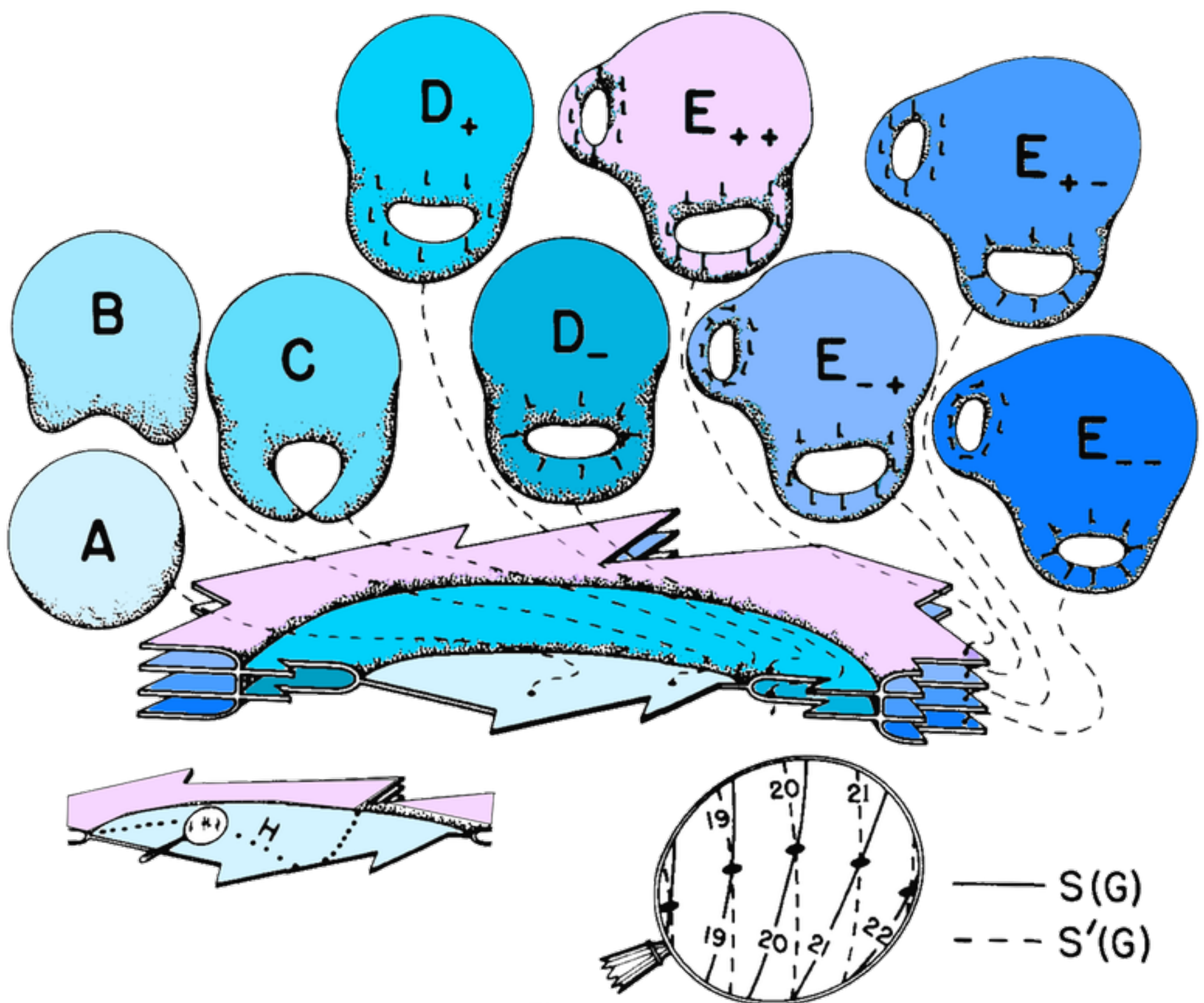
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present the handles which let them be identified as *wormholes*. In a multiply connected space they have to be expected behaviours looking strange as seen from our many-3-geometries-at-once point of view. Imagine two identically coloured pink cubes. Also, oriented the same way with respect to a single triad. Let one them enter the wormhole by one of its throats. Let the other cube move along the flat surface out of the handle, from the same throat where the other get in, til the other throat. You'll discover they'll get rejoin themselves differently oriented with respect to the triad used as a reference when they get in ! This kind of geometric structures are an unavoidable feature of the space. The Readers may immediately consider the risk to introduce Closed Timelike Curves (CTCs) in the structure of the space. These risks exist applying the General Relativity theory, without the conditioning of the modern version of the Principle of Superposition, of quantomechanical origin object of deeper analysis in following sections. As a matter of fact, CTCs are really introduced but on timescales extremely small ($\sim 10^{-43}$ s), giving effects completely uneligible in our macroscopic measurements.

The synthetic and technological meaning of all what preceded is that General Relativity, a theory made of worldpoints (the Events), constitutes *a device to calculate and constructing a leaf of history that slices through the higher dimensional space S* . The dimensionality of S is at least 4.



▲ When two surfaces are joined by different wormholes, full justice is made for the use of the mathematical term *multiply connected space*. The example is showing what can be: 1) two multiply connected leaves. 2) a single multiply connected leaf joint in an area not visible in the image (image credit S. Hossenfelder, 2014)



▲ A multiply connected manifold. The foliated (or, multisheeted) character of space is distinctly visible, jointly with those topologic peculiarities whose constructive interferences we name Events or Measurements. Each one of the differently coloured volumes visible is 4-dimensional. Each one black dot is a 3-dimensional volume: each one of the *points* A, B, C,... contains the infinite amount of points existing in a 3-dimensional space. Smooth lines numbered 19, 20, 21, 22 are wave crests of probability amplitude function $\Psi_E(x, t)$, where E is the Energy, x a spatial coordinate and t the time parameter.

Dashed lines, the same for an energy $E + \Delta E$. $S(G)$ and $S'(G)$ are the Hamilton-Jacobi dynamical phases due to different waves, their elliptic intersection points being regions of constructive interference, what we normally name *particles*. In the year 2000, it has been discovered (Deutsch, 2000) that the information flow at the quantum level follows the basic rules of the flow of information between different 3-geometries in a multiply connected 4-dimensional manifold like the one here depicted. A convergence between Quantum Gravity's studies of 50 years ago and the field of Quantum Information which arose recently by the new key concept: the Multiverse (abridged by image credit J. A. Wheeler *et al.*, 1973)

Triggers, the simplest thinkable instance of all kinds of electronic inspection measurements, are one of the ways to differentiate leaves otherwise similar.

This means that the true purpose of the Triggers is to acquire information about the phase, state, dynamic or kinematic conditions of an object. We are used to think and write this is made always and only on the base of a reference point of Time, a clock integral part of all Shifting Registers. In the reality, Time is an apparent effect of the relation or, to be more precise, of the *entanglement* of a multitude of individual measurements happenings only in separate non-communicating 3-dimensional spaces, foliated to form a 4-dimensional. We, and our Detectors, occupy a multitude of these 3D leaves along a single constructive interference crest. That’s why we feel Dynamics.

Hilbert: measurements in another space

Methods and formalism of Quantum Mechanics, different than those of Relativity, established that subsystems evolve separately, along a tree-like structure occupying a multitude of spaces.

Multitude of spaces, in some way reminiscent of the (infinite) multitude of spaces since 1907 attributed by Relativity theory to each one instant of time. The information about the entire set of historical time-ordered ramifications, only known to the system superposition of all of the subsystems, named Multiverse, and never fully known to the subsystems. Causing what, from the sub systems point of view, is the existence of limits to knowledge, synthesized in the Uncertainty Principle. Multiverse is an idea implicitly embedded since the start in the same wave function Ψ . The same function describing how, as an example, semiconductor-based transistors operate grouped into the Integrated Circuits of the Bottling Controls (Electronic Inspectors).

Ψ , originally only born to define the probability to localize the electron of an atom, since the start spread the answer in the infinite range of positions x . Erwin Schroedinger, the nobelist who fathered in 1926 the wave function formalism on the base of prior ideas of Louis De Broglie, saw that the wave function Ψ was describing a multitude of simultaneously coexisting electron positions in the space \mathbb{C} of complex numbers $\{ a + i b, \ a,b \in \mathbb{R} \}$ rather than a single position in the space \mathbb{R} whose elements are real numbers. Schroedinger choose to treat the multitude of solutions in the particular case he studied (*a multitude of electrons in a Hydrogen atom*), the way we treat square roots of minus one in \mathbb{R} . They were necessary other thirty one years to let someone else, Hugh Everett III, recognise their physical relevance and meaning. The wave function Ψ representing a physical field, and each one solution different than the others for a minimum amount of Information. Amount today considered equal to 1 bit.

The example we considered before, should have fully satisfied Maxwell’s equation **[3]** in case of an *ideal RLC serie circuit*, something which never existed nor shall exist:

- in an Environment whose temperature is kept constant with an infinite precision;

“...measurements (and, triggerings) of the Electronic Inspectors, are exclusively happening between different 3-geometries where we, our devices and machinery, exist”

Complex numbers does matter

Do you remember the handling given to $\sqrt{-1}$ when solving equations like:

$$a x^2 + b x + c = 0$$

into the set \mathbb{R} of real numbers ?
Solutions given by relation:

$$x_{1,2} = \pm (b^2 - 4ac)^{0.5} / 2a$$

may imply square roots of negative numbers.

An example in the case:

$$x^2 - 1 = 0$$

whose roots are:

$$x_{1,2} = \{-1; 1\}$$

- in an Environment whose humidity is kept constant with an infinite precision;
- no Environmental electromagnetic fields;
- no gravitational fields, say, RLC circuit in a flat never existed Euclidean space-time;
- no induction of the electromagnetic field of the inductor in the resistor and capacitor, etc.

In other terms: ideal subsystem RLC components and no Environment around. Conditions like these can only be encountered out of the Universe, because they imply no electromagnetic nor gravitational fields. On practice, a **system causally disconnected (then, non correlated) by the Environment**. In 1935 Schroedinger conceived a case where a complex (biologic) system lies in an ambient assuring total disconnection from the external world, the Environment. He was the first to understand that an object lying in a truly closed ambient, without any exchange (no matter, radiation nor information flow) with the external ambient, should have been in a super position of states, rather than in the single one we perceive directly or by mean of measurement instruments. In this case, the insulated system should have had a multiple existence: different statuses of different instances of the system in the insulated ambient.

The object should have been:

- out of the Environment;
- into an infinite-dimensional space, where a multitude of instances of the system exists.

How this may be possible also depends on the fact that Ψ is defined in the Hilbert space, a vector space itself generalization of the known \mathbb{R}^3 Euclidean space. Hilbert space extends the methods of vector algebra and calculus from the three-dimensional space to spaces with any infinite number of dimensions. Here, we are using the term *dimension* in the usual way as the quantities fully defining the position of a point in the space. Imagine a dot and let all infinite radiuses spherically get out of that dot: that is the dimension of a dot in the Hilbert space, where each one radius identifies each one of the properties (e.g., position, time, momentum, polarization, curvature, action, energy, temperature, information, etc.) of that dot.

As an example, of the differences existing between the classic Euclidean and the modern Hilbert space, consider two classical independent systems for which we know:

- the Euclidean position, in the 3-dimensional space (x, y, z);
- their velocity components, along each one of these axes (**V**_x, **V**_y, **V**_z).

If we join these two systems and let them interact, we *add the number of dimensions of each one* of them. The system derived by the superposition of the two original systems, each one described by 6 dimensions, is fully described by 12 dimensions. But, repeating exactly the same steps in the Hilbert space carries a completely different result because we have now *to multiply the number of dimensions* of the original systems. Then, in this case the dimensionality necessary to fully describe the superposed system increases to 36. More, in **the Hilbert space the superposition of two systems** like that described before (a measurement) **is noncommutative [6]**, meaning that the order of the operations implies different results.

A binary operation * on a set S is **noncommutative** if, for all x, y ∈ S:

$$a * b \neq b * a \qquad [6]$$

This last point truly makes the difference with respect to a common sense still based on the classic Algebra of real numbers functions in the set \mathbb{R} of elements in the same set \mathbb{R} . Our idea of commutativity is strictly related to the deeper idea of symmetry. How can be possible that a different order in the operations change the result ?

Negative roots of minus one are considered roots without signification in the set \mathbb{R} . As a matter of fact, on the opposite these same roots have full meaning (also physical, e.g. when dealing with concepts of reactive power in Electrotechnics and resonance in Electronics) when the solution of the equations is extended to the set \mathbb{C} of the complex numbers, of which the real numbers \mathbb{R} are just an infinitesimal subset.

“Triggers, the simplest thinkable instance of all kinds of electronic inspection measurements, are one of the ways to differentiate leaves otherwise similar”



▲ **The iridescent reflection of light, visible in the diffraction grating of DVDs, is an example of decomposition of the frequencies**

An idea like this, judged from the familiar point of view of the Real numbers seems unthinkable, as an example suggesting that:

$$2 \cdot 3 \neq 3 \cdot 2$$

After the implications of non commutative rules became evident, it was coined a first comfortable tentative explanation, one trying to pass around the new scenario it forced to front:

“No paradox exists: we are treating non-classic complex operators in the space of Hilbert”.

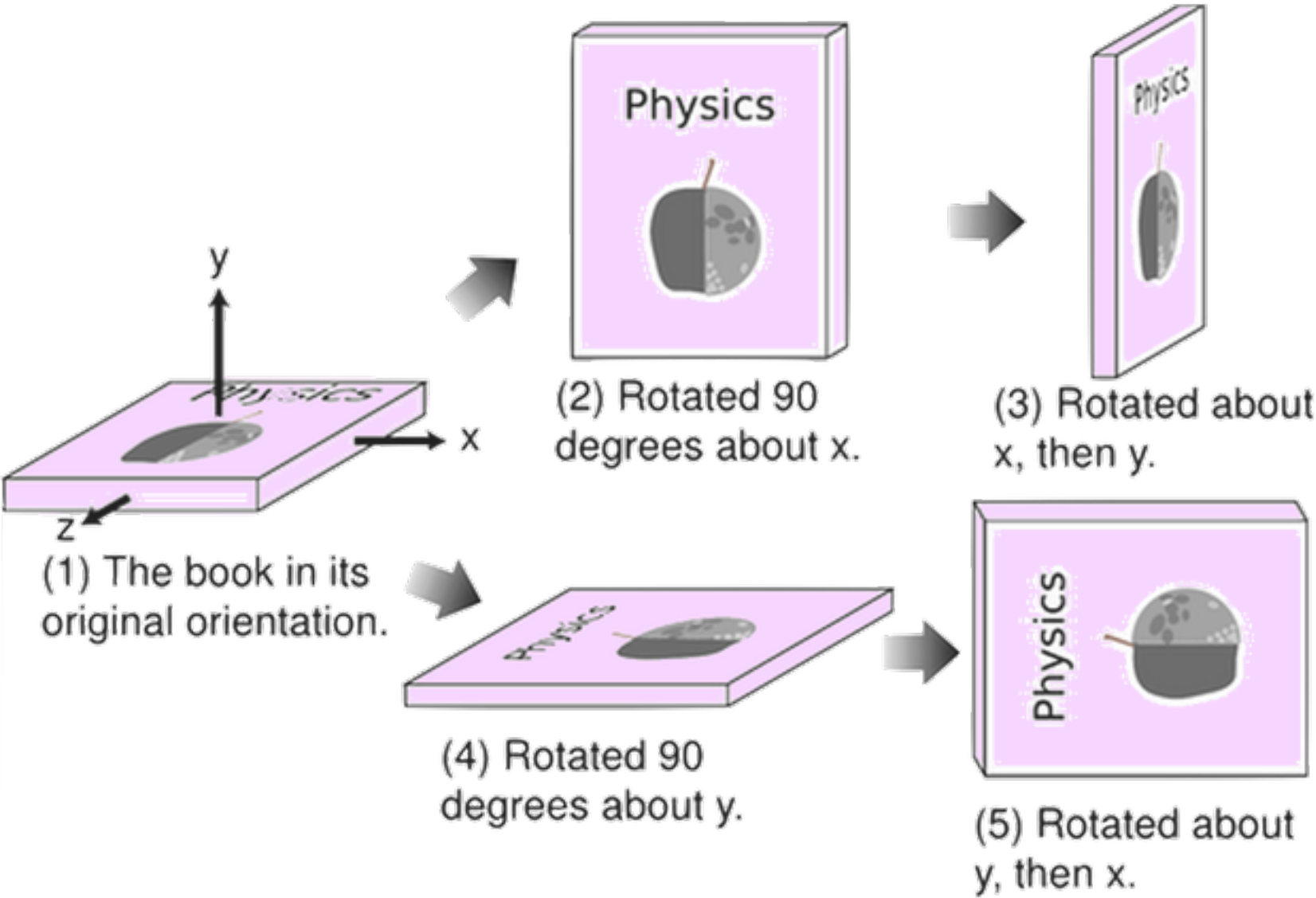
But, the Hilbert space is yet the base for all practical technological applications. How can it be possible that *a useful fiction, a mathematical-only artifice* could carry us such a bonanza of Wall Street-quoted technological and industrial applications ? As an example, no one doubts about the reality of the switchings of the CPUs and of the logic gates in the Programmable Logic Controllers (PLCs) which let worldwide Food and Beverage Bottling Lines run in this moment. No one doubts that what those CPUs and I/Os are performing, are computations over a programmed algorithm. A second attempt to pass around the uncomfortable implications of the reality of the Quantum Field, tried to limit to the atomic and subatomic scales the domain of application of noncommutative geometry rules. But, other examples of noncommutativity were yet known also for objects of the spacetime macroscale of dimensions we directly perceive without any instrumental aid. As an example the geometric rotations of a solid, massive 3-dimensional book, in the figure below. Then, non commutativity represents rules of general application.

The key point is that **Hilbert space represent a system before the measurement action when all of the states of the system exist in superposition.** *The act to measure a status for a variable (or, Trigger, e.g. the time of passage of a container front of a photoelectric sensor) reduces the observed value to a single point, ...what does not mean that the others do not exist any more or they did not existed at all before the measurement.*

Additional confirmations that Quantum Mechanics had since the start the multiversal scenario deeply embedded into its logic. The tree-like branching logic which explains why and how our industrial world exists and operates.

superimposed to form the incident solar light. Examining individual photons, rather than the multitudes of the classic Geometric Optics, deserves surprises about photons' nature

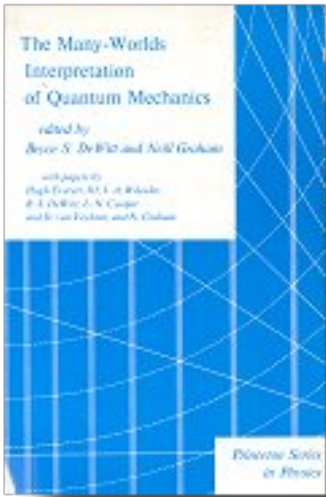
"Hilbert space represents a system before the measurement action, when all of the states of the system exist in superposition”



On left side: rotations in three dimensions of a solid are non commutative (abridged by Jeff Atwood, 2011)

In the next section we'll explore the amazing answer slowly discovered along last sixty years.
One built over the modern quantum version of the Principle of Superposition.

Modern version of the Principle of Superposition



“We wish to make statements about ‘trajectories’ of observers. However, for us a trajectory is constantly branching (transforming from state to superposition) with each successive measurement”

Hugh Everett III, 1957

(hugh-everett-iii-dissertati.pdf)

Everett original dissertation
(hugh-everett-iii-dissertati.pdf)

Introduction

When treating before the revolutionary ideas of Relativity, we saw the Relativity Principle implying many times and spaces, which in turn implies that the world is 4-dimensional. This explained why Michelson and Morley's experiments failed to determine absolute movements with respect to an *Ether*, supposed the spatial absolutely steady reference system. **No absolute motion exists, since there are infinite 3-dimensional spaces, not just one, referred to each one instant of time.** This idea about the existence of an infinity of 3-dimensional spaces associated to a single instant of time we have to keep present when thinking to the organization of *all* into systems and subsystems.



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164 pages, 4.3 MB
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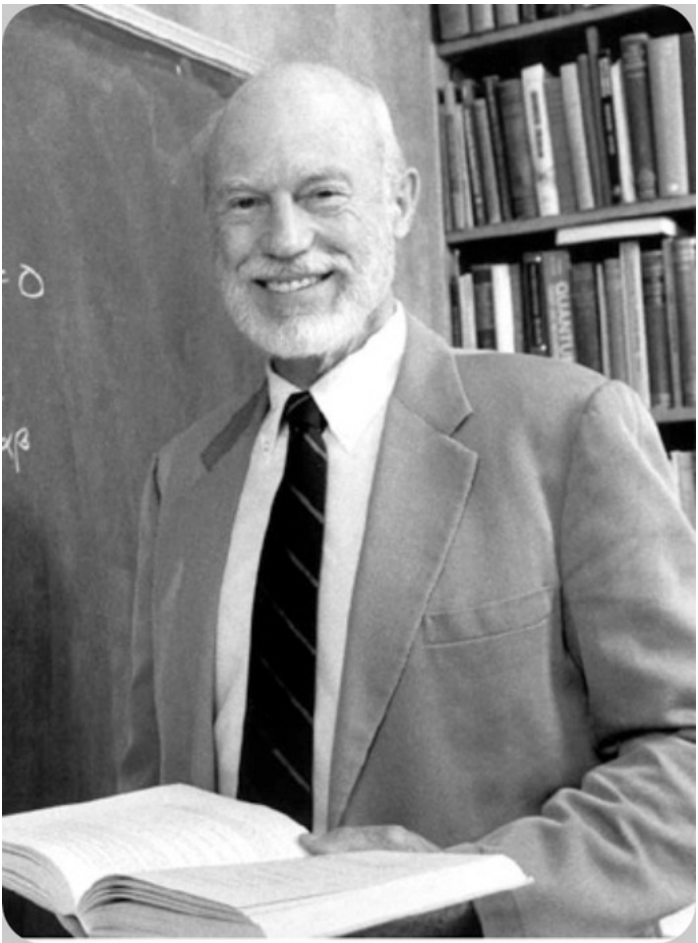
▲ **Hugh Everett, III, physicist and mathematician**

Also, the classic Principle of Superposition cited above is still presently being presented in the elementary textbooks of Physics and Electrotechnics in the high-schools and in the University courses for future Electronics and Telecommunications Engineers. What only a few (mainly Physicists and Mathematicians) know is that the Classic Principle underwent a radical revision after 1957. A graduate student of Princeton University, Hugh Everett III, as part of his doctorship dissertation presented a new interpretation of the Quantum Mechanics theory, including a revision of the Principle of Superposition and a theory of Measurement. The book on side, a Princeton Series in Physics edition of 1973, includes the 164-pages long dissertation by Everett (Princeton University Press, Cambridge, Mass., USA). A book today only available thru worldwide Physics' Department libraries. The comprehensive dissertation, occupying more than one-half of the academic text, can be downloaded by several academic web sites: here, on right side, it is included for download (hugh-everett-iii-dissertati.pdf).

In synthesis

Bryce Seligman DeWitt, who edited the collection of papers (DeWitt, 1973) in the publication cited before, wrote a Preface we prefer not to abridge, rather to quote in the following. It offers a straight and clear insight on the *machinery* underlying "The Theory of the Universal Wave Function", including the modern version of the Principle of Superposition:

"In 1957, in his Princeton doctoral dissertation, Hugh Everett, III, proposed a new interpretation of quantum mechanics that denies the existence of a separate classical realm and asserts that it makes sense to talk about a state vector for the whole universe. This state vector never collapses and hence reality as a whole is rigorously deterministic. This reality, which is described jointly by the dynamical variables and the state vector, is not the reality we customarily think of, but is a reality composed of many worlds. By virtue of the temporal development of the dynamical variables the state vector decomposes naturally into orthogonal vectors, reflecting a continual splitting of the universe into a multitude of mutually unobservable but equally real worlds, in each of which every good measurement has yielded a definite result and in most of which the familiar statistical quantum laws hold. (...) Looked at in one way, Everett's interpretation calls for return to naive realism and the old fashioned idea that there can be direct correspondence between formalism and reality"



▲ **Bryce G. DeWitt, the physicist who published the theory by Everett, including the Principle of Superposition in its modern version (image credit Larry Murphy)**

The debate

What immediately before DeWitt wrote, hints to a fact: Everett’s interpretation of Quantum Mechanics (QM) is the simplest and straightest statement about what QM is saying us. Everett's understanding of QM formalism was such to determine the first real step by step analysis of what really a Measurement is. In the debate about the interpretation of QM, Hugh Everett III was a follower of Albert Einstein's position. To have an idea of the ‘philosophy’ accompanying the “shut up and calculate” imposed *credo*, Copenhagen's interpretation was insisting that *eality is attributed to objects by the observation*. Einstein and Everett, on the opposite, are convinced defenders of the idea that *Reality exists unrelated to Measurements and existed before any human started to observe Nature*.

A historically new and deeper operative meaning had been established for the Principle of Superposition, marrying Bayesian Statistics to the ideas of the Schroedinger equation **[5]**:

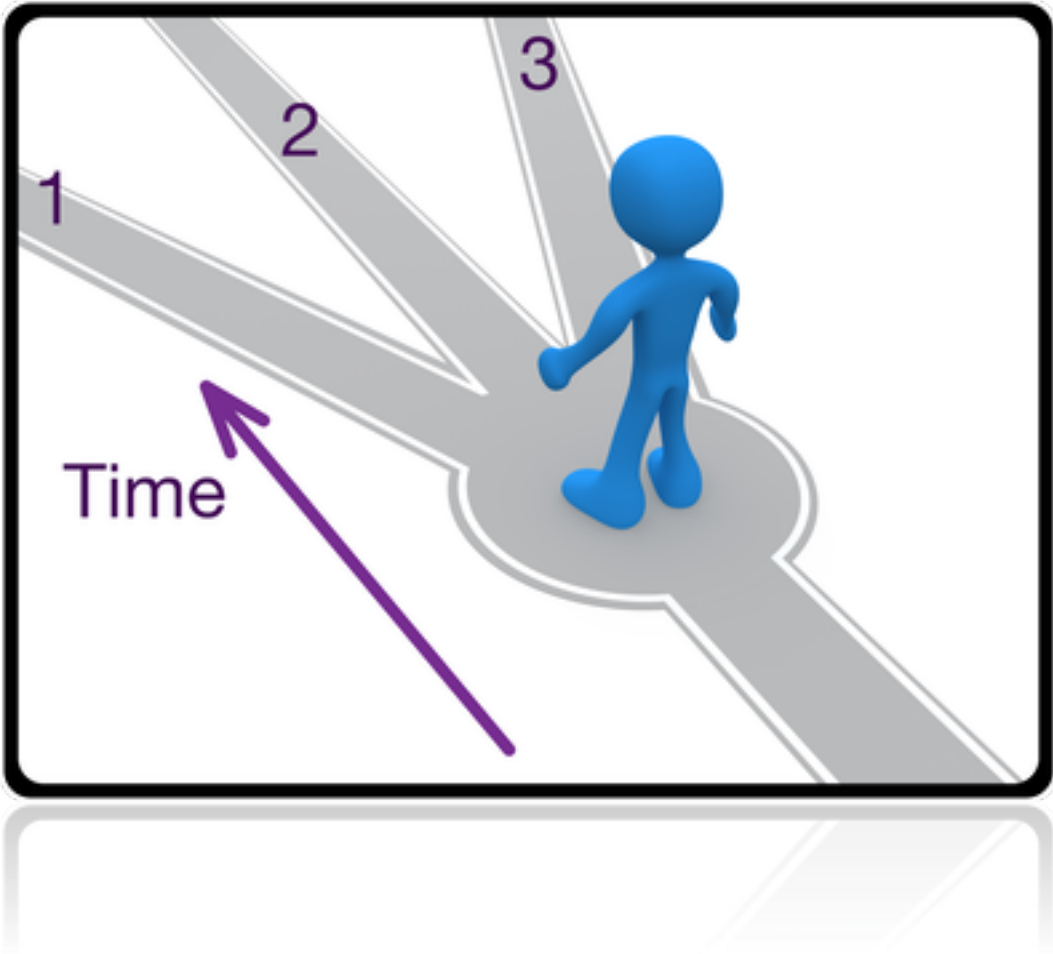
$$i\hbar \frac{\partial}{\partial t} \psi(\mathbf{r},t) = -\frac{\hbar^2}{2m} \nabla^2 \psi(\mathbf{r},t) + V(\mathbf{r},t) \psi(\mathbf{r},t) \tag{5}$$

where:

- i imaginary, defined in the set \mathbb{C} of complex numbers $\{ a + i b, a,b \in \mathbb{R} \}$ say $\sqrt{-1}$;
- $V(r, t)$ potential energy influencing the particle;
- m mass of the particle;
- \hbar Planck constant divided by 2π , equal to $1.05459 \times 10^{-34} \text{ J s}$
- $\psi(r, t)$ wave function, defined over space and time;
- ∇^2 Laplacian operator:

$$\frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2} + \frac{\partial^2}{\partial z^2}.$$

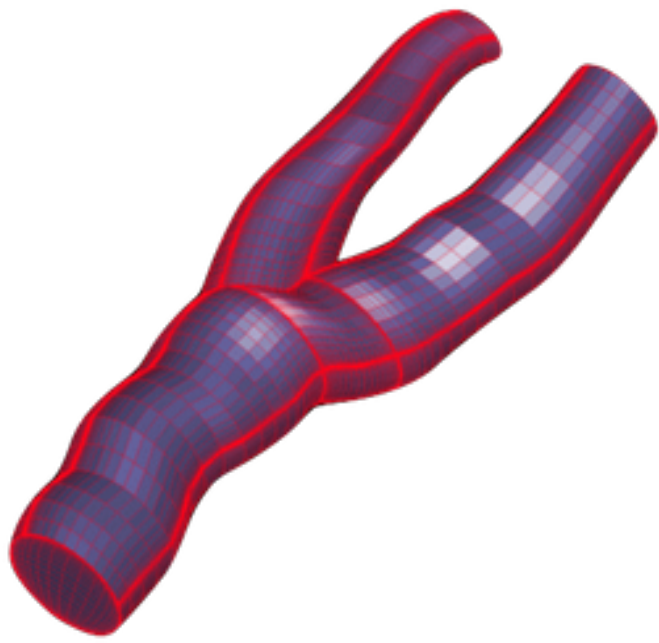
A meaning where the wave function Ψ is the fundamental entity, obeying at all times a deterministic wave equation. This picture only makes sense when observation processes are treated within the theory. It is only in this manner that the apparent existence of definite macroscopic objects, as well as localized phenomena (such as tracks in cloud chambers), can be satisfactorily explained in a wave theory where the waves are continually diffusing.



On side: after 1990 it became clear that choices in the way-outs are apparent. All of them are explored. Following modern insights of String Theory and Quantum Mechanics, to that instant of time are referred many more results than the 3 here visible. Each result an Event itself, triggered in correspondance to different properties. In the last few years they had been experimentally observed on macroscopic scales the less intuitive results

A deduction of this theory is that phenomenas will appear to observers to be subject to the discontinuities which are everywhere observed. The *quantum-jumps* exist as relative phenomena (e.g., the states of an object-system relative to chosen observer states show this effect), while the absolute states change quite continuously. And that's why one of the names of the theory is Relative State formulation. Each one result is not less true and real than the others. We are indicating in the figure above this multitude of coexisting, rather than alternative, histories by mean of the three ways branching out of a single. The new Principle is capable to include the entire step-by-step evolution of a system composed of subsystems. And, what is most important, this modern version holds for any system of Quantum Mechanics for which the classic version of the Superposition Principle holds and is applicable to all physical systems, regardless of size.

As a consequence, what in these pages is being presented is the most modern conception of Measurement.



▲ A trajectory is constantly branching, transforming from state to superposition, with each successive measurement.

The Hilbert space represents a System before the Measurement, when all of the states of the System exist in superposition. What visible above is Everett's original idea, where Time has the direction of the branching. Also the opposite happens, where branches join themselves: this is the modern meaning associated to the classic term *interference*

How do we know a bottle is closed ?

The formalism of the version 1957 of the Principle of Superposition (on left side), can be translated in practical terms by mean of an example referred to a cap presence digital inspection, in a Bottling Control. We choose the Cap

The Principle

In the following the text of the modern version of the Principle of Superposition due to Everett, where:

- A is a quantity with eigenfunctions Φ_i^{S1} measured in a system $S1$ by an Apparatus;
- $a_i = (\Phi_i^{S1}, \Psi^{S1})$ are the projections on the eigenspaces of the different eigenvalues of A, after the measurement;
- the brackets [...] denote values recorded in the memory of the measurement apparatus.
Exactly what invariably happens to the measurements performed by the nonclassic subsystems (namely, *detectors' semiconductors*) of other subsystems (*inspections*) of those apparatuses we name Electronic Inspectors.

“ For any situation in which the existence of a property R_i for a subsystem $S1$ of a composite system S will imply the later property Q_i for S , then it is also true that an initial state for $S1$ of the form:

$$\Psi^{S1} = \sum_i a_i \Phi^{S1}[R_i]$$

will result in a later state for S of the form:

$$\Psi^S = \sum_i a_i \Psi^S[Q_i]$$

which is also a superposition of states with the property Q_i . That is, for any arrangement of an interaction between two systems $S1$ and $S2$ which has the property that each initial state:

$$\Phi^{S1} \Psi^{S2}$$

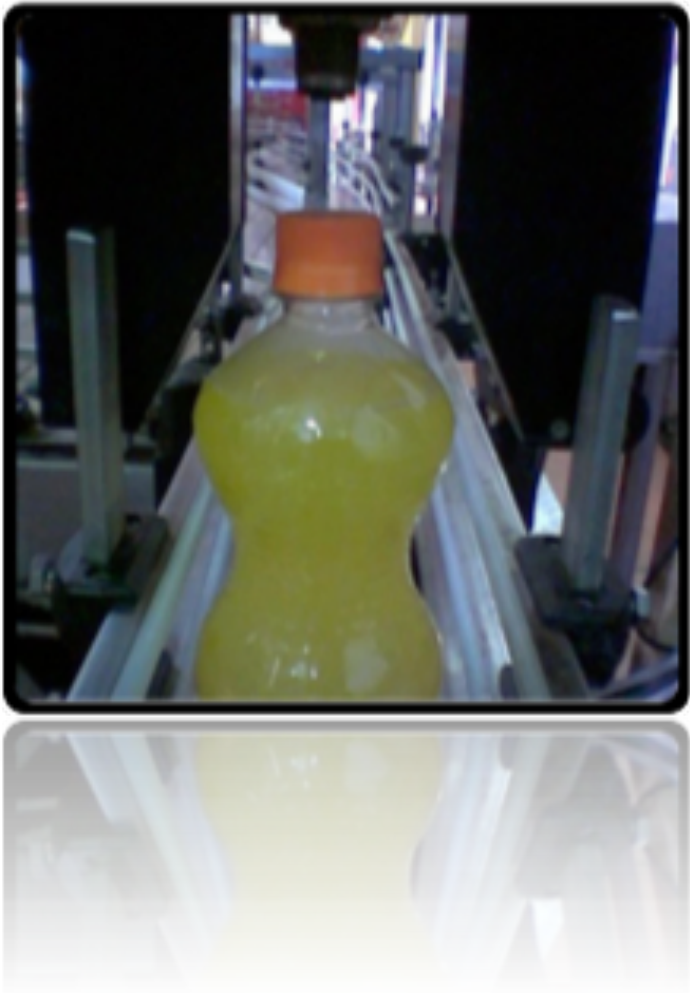
will result in a final situation with total state $\Psi^{S1 + S2}$, an initial state of $S1$ of the form:

$$\sum_i a_i \Phi^{S1}$$

will lead the whole system, after interaction, to the superposition:

$$\sum_i a_i \Psi^{S1 + S2} \dots\dots$$

Presence inspection because one of the simplest existing, then easier to imagine also for non-specialists. One of these is visible in the figure below.



▲ An everyday life object, a PET bottle, immediately before to establish a strict however brief superposition of states with two aparatuses, acting as measurements systems. The lateral black colour fork-like couple of objects being an high frequency (27 MHz) radiator to detect the filling level. The upper central cylindric object, being a Photoscanner devoted to Cap Presence inspection, including a LED illuminator and a light detector based on a phototransistor

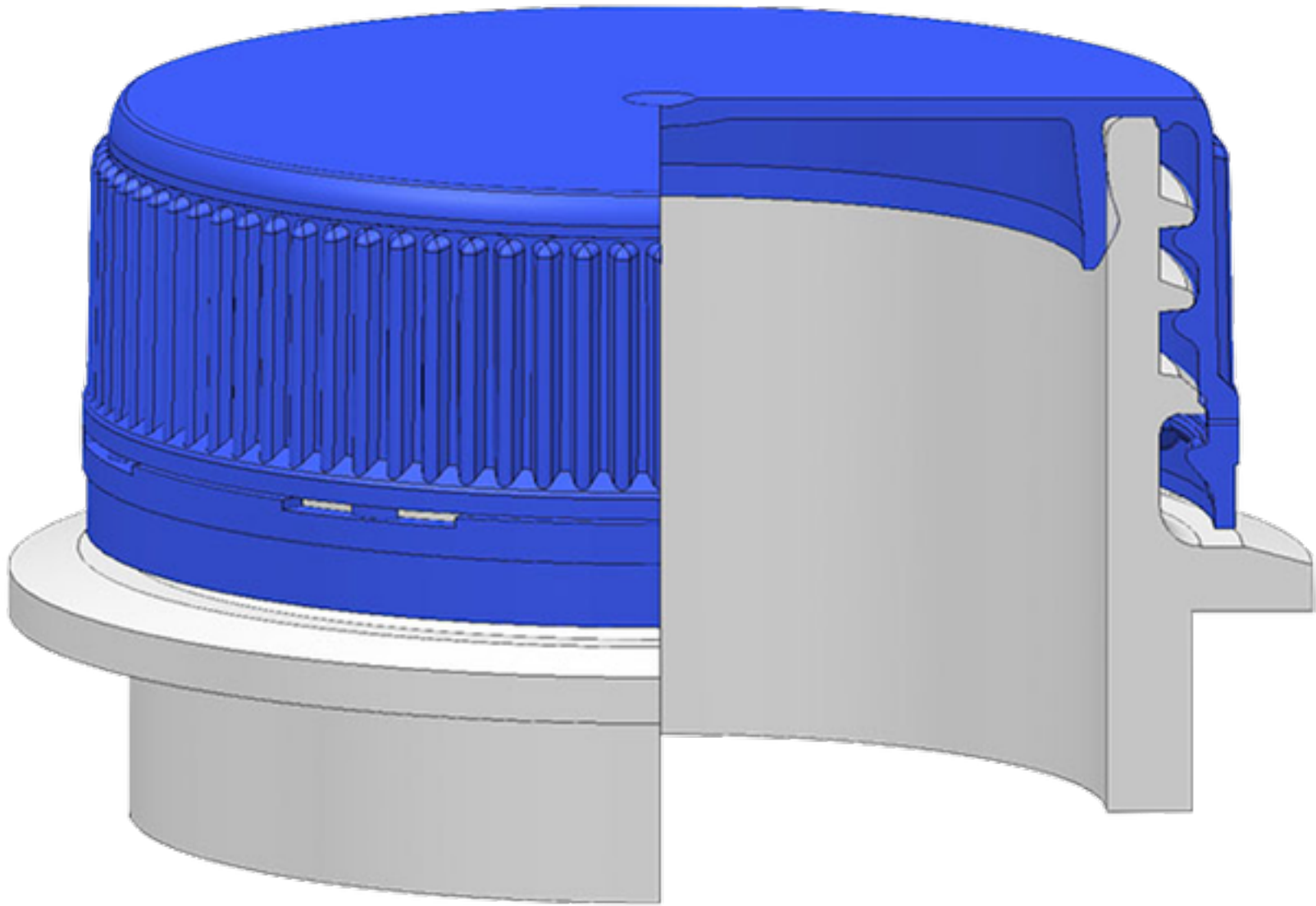
Let:

S composite system.

The *apparatus* we name Cap Inspection in a Bottling Control with several kinds of inspection, and a cap mainly composed of Carbonium atoms;

$S1$ subsystem of the system S .

An atom of Silicium in the phototransistor which have to detect the reflection of a 700 nm photon (emitted by a LED



▲ The atoms of Carbonium in the screw of this *Bottle* were yet correlated with the Carbonium atoms we name *Cap* well before they were aggregated in that shape by a Cap Moulding Machine. Each one atom of Silicium today functionally shaped and doped to act as detector of the reflected wave packets, indicating presence of a cap, in the Cap Presence inspection of a Food and Beverage Bottling Control, is correlated with all other existing particles. To measure by mean of a photoscanner the property *closure*, means to establish a cap-photoscanner state describing the photoscanner as definitely perceiving that particular system state. But, to definitely perceive a cap-photoscanner state, it is necessary ...time. Time to transform the previous state, in which all possible kinds of correlation of the Photoscanner coexist, in a following state in which the Photoscanner is “aware” to be correlated to a Cap, because having recorded eigenvalues for the eigenfunction Φ_i^{S1} describing a Cap.

The modern meaning of *repeatability* and *false positives*

Photoscanners are the modern version for what long time ago was known as *Photoelectric cells*. They have common use in a huge amount of technological industrial applications. Are interesting because designed in such a way to *emulate* the neuronal chains, like those comprised between the retina and the groups of neurons in the lobes, devoted to perception.

To determine that a bottle is capped by mean of a Photoscanner, say to definitely perceive a Cap-Photoscanner state, it is necessary:

1. Time, to transform the previous state, in which all possible kinds of correlation of the Photoscanner coexist, in a following state in which the Photoscanner is “aware” to be correlated to a Cap, because having recorded eigenvalues for the eigenfunction Φ_i^{S1} describing a Cap. The correlation between the two systems Photoscanner and Cap) is progressively established during interaction and proportional to the natural logarithm ($\ln t$) of the interaction time t . An ideal correlation, corresponding to a maximised information of the Photoscanner about the Cap, can only be reached allowing an infinite time. This causes the measurements’ fluctuations, a synonymous of the spectrum of the eigenvalues, resulting in the Electronic Inspector false positives (false rejects). Time to transform the previous state, in which all possible kinds of correlation (superpositions) of the Photoscanner coexist, in a following state in which the Photoscanner is *aware* to be correlated to a Cap, because having recorded eigenvalues for the eigenfunction Φ_i^{S1} describing a Cap.

encased in the same Photoscanner) indicating the status of present cap;

S_2 subsystem of the system S .

An atom of the cap, which can be present or absent;

R_i property of the subsystem S_1 .

The energetic level of the Silicium atom, high after absorption of a red colour photon whose wavelength is 700 nm;

Q_i property for S , after the establishment of the correlation (superposition, namely a bifurcation) between S_1 and S_2 ;

Then:

$\Psi^{S_1 + S_2}$ wave function after interaction of S_1 and S_2 .

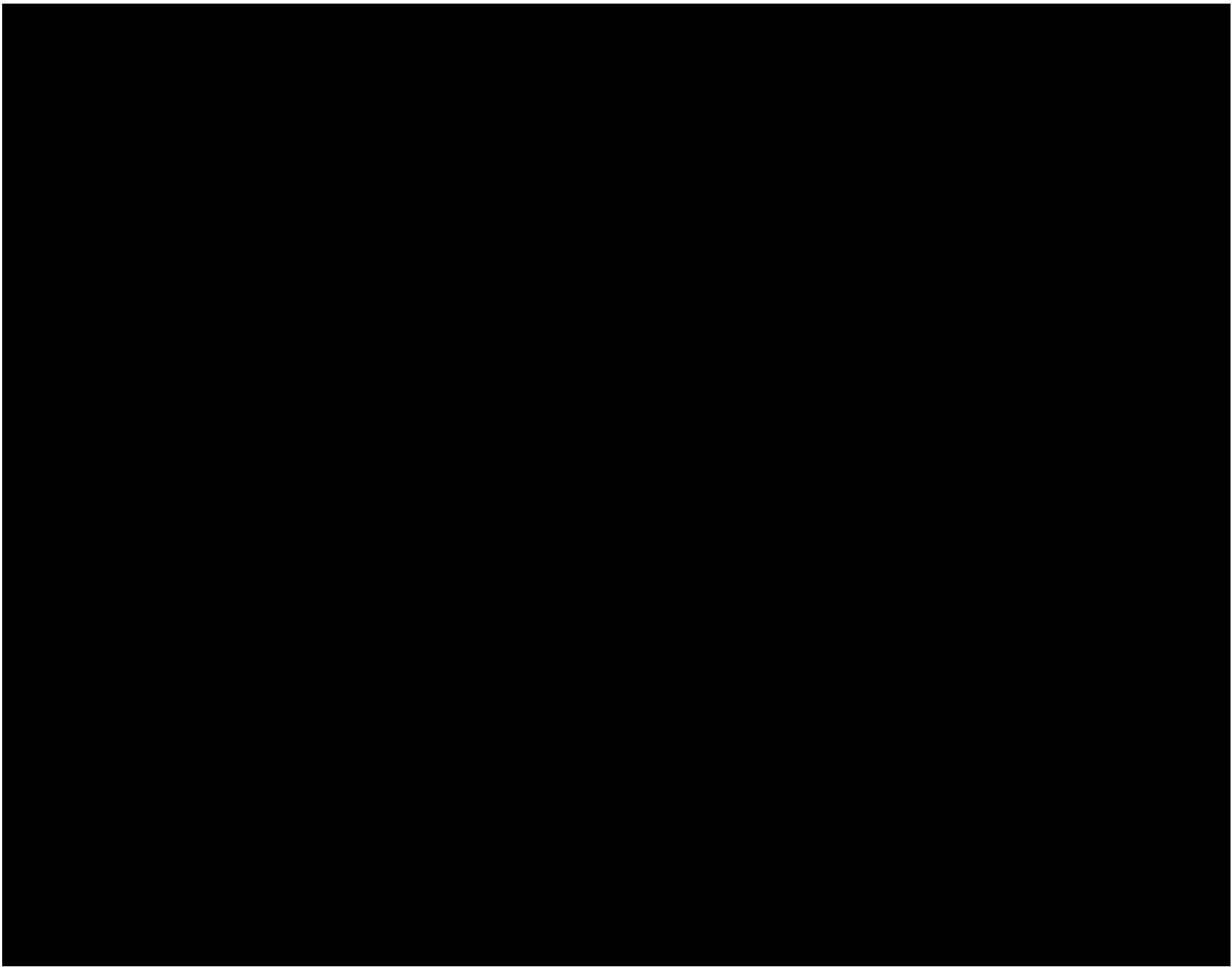
Wave function encoding the status of the atom in the cap and of the atom in the phototransistor of the Photoscanner, whose laymen translation is: "Cap Present".

and:

$\sum_i a_i \Psi^{S_1 + S_2}$ eigenstate in which the apparatus has recorded an eigenvalue.

Relative state in which a component of the Cap Presence inspection, namely an atom of Silicium of the phototransistor into the Photoscanner, has increased its own energetic level after having absorbed a 700 nm photon reflected by an atom of Carbonium of the cap

2. Interaction between the systems such that the information in the marginal distribution of the object inspected is never decreased. Otherwise we could not have any more repeatability of the measurements. As an example, this should be the case if we'd erroneously try to use a beam of high energy neutrons, rather than LED's low energy photons, to interact with the Cap. The nuclei should modify the molecular structure of the Cap, modifying its eigenstates and then the eigenvalues we expected to derive by the measurement.



Individual wave packets, whose length is 700 nm, emitted by a red LED can be reflected back to a phototransistor encased jointly with the LED to form a Photoscanner, by an atom of Carbonium of the many composing what we name a cap, applied over a passing bottle. The correlation between the two systems Photoscanner and Cap) is progressively established during interaction and proportional to the natural logarithm of the interaction time [$\ln(t)$]. An ideal correlation, corresponding to a maximised information of the Photoscanner about the Cap, only allowing an infinite time. This causes the measurements' fluctuations, a synonymous of the widened spectrum of the eigenvalues, resulting in the Electronic Inspector *false positives* (false rejects). The interaction between the systems has to be such a way that the information in the marginal distribution of the object inspected is never decreased, otherwise we could not have any more *repeatability* of the measurements. As an example, if we'd erroneously try to use a beam of high energy atomic nuclei, rather than LED's low energy photons, to interact with the Cap. The nuclei could easily change the molecular structure of the Cap (damaging it) changing its eigenstates and then the eigenvalues we expected to measure

Theorems born for Automatic Machines

QUESTION:

Does the new version of the Principle of Superposition applies to the subset of Binary Classifiers named Electronic Inspectors (Bottling Controls) ?

ANSWER:

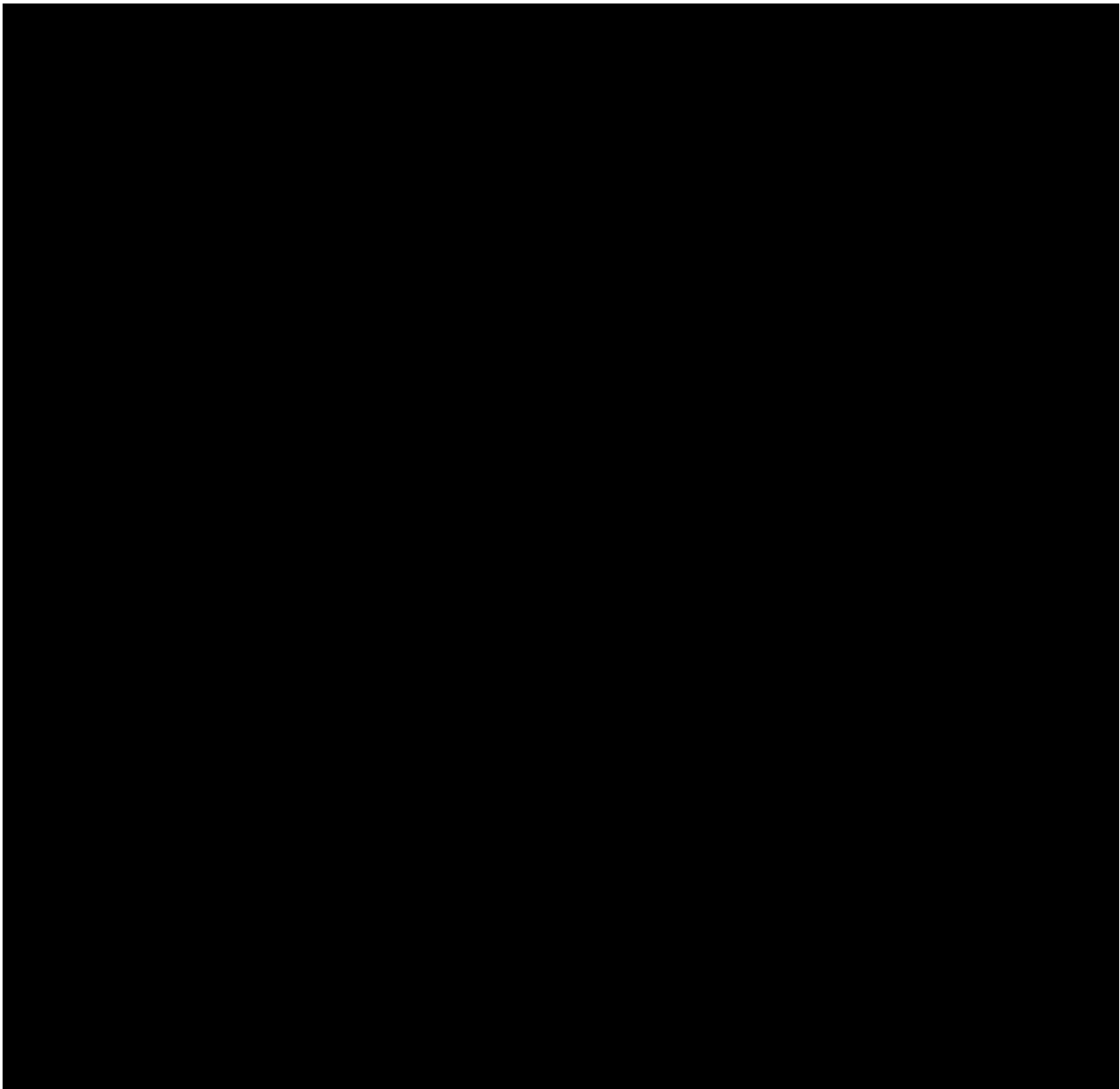
Strictly. The new scenario was conceived for systems equipped and behaving the same identical way a common Bottling Control (or, Electronic Inspector, or Binary Classifier) is equipped.

Devices with memory and capability to process measurements values incoming by sensors and data into its memory, to decide future actions. In the following, we'll directly quote Everett's words (in DeWitt, 1973, page 64) to clear this relevant point:

"As models for observers we can, if we wish, consider automatically functioning machines, possessing sensory apparata and coupled to recording devices capable of registering past sensory data and machine configurations. We can further suppose that the machine is so constructed that its present actions shall be determined not only by its present sensory data, but by the contents of its memory as well. Such a machine will then be capable of performing a sequence of observations (measurements), and furthermore of deciding upon its future experiments on the basis of past results. We note that if we consider that current sensory data, as well as machine configuration, is immediately recorded in the memory, then the actions of the machine at a given instant can be regarded as a function of the memory contents only, and all relevant experience of the machine is contained in the memory. For such machines we are justified in using such phrases as *the machine has perceived A* or *the machine is aware of A* if the occurrence of *A* is represented in the memory, since the future behavior of the machine will be based upon the occurrence of *A*. In fact, all of the customary language of subjective experience is quite applicable to such machines, and forms the most natural and useful mode of expression when dealing with their behavior, as is well known to individuals who work with complex automata". What above can be depicted in an intuitive image, one where the Minkowskian world sheet introduced in the starting sections of this web page, is swept out by stringlike particles as they move and interact in spacetime (see figure on right side).



▲ A first glimpse to the true nature of the Measurements: the fabric of a 2-brane is a web of bifurcations and interferences. Measurements are both topologic changes, bifurcations or interferences, experienced by the topologic variety, whose character is visibly *multiply-connected* (image credit M. Green, 1986)

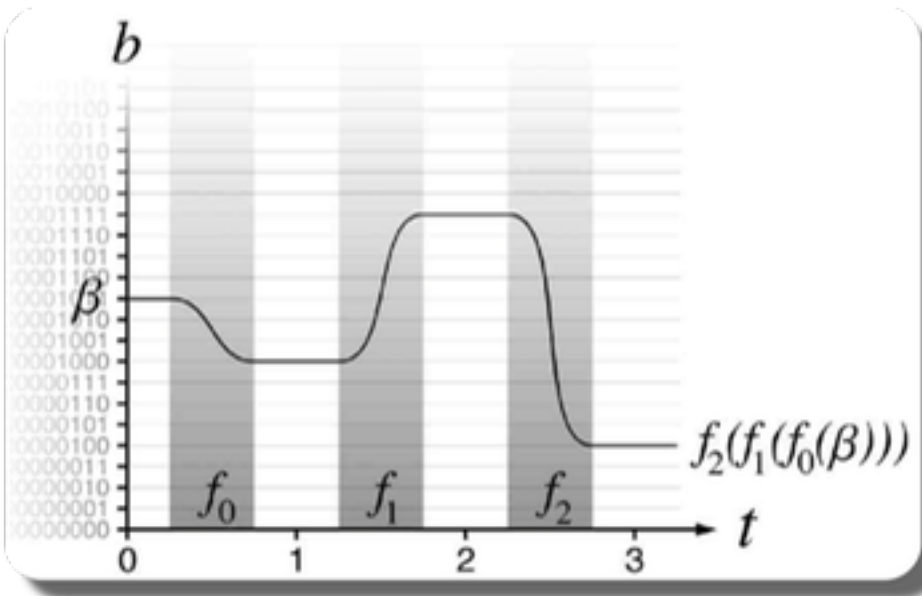


▲ The modern version of the Principle of Superposition is a straight explanation of the process of measurement and of the deriving superposition of states, withouth anything else added. It is firmly based and continously reconfirmed by an impressive amount of experiments and practical technological applications. Each spectrum of light evidences quantum superposition

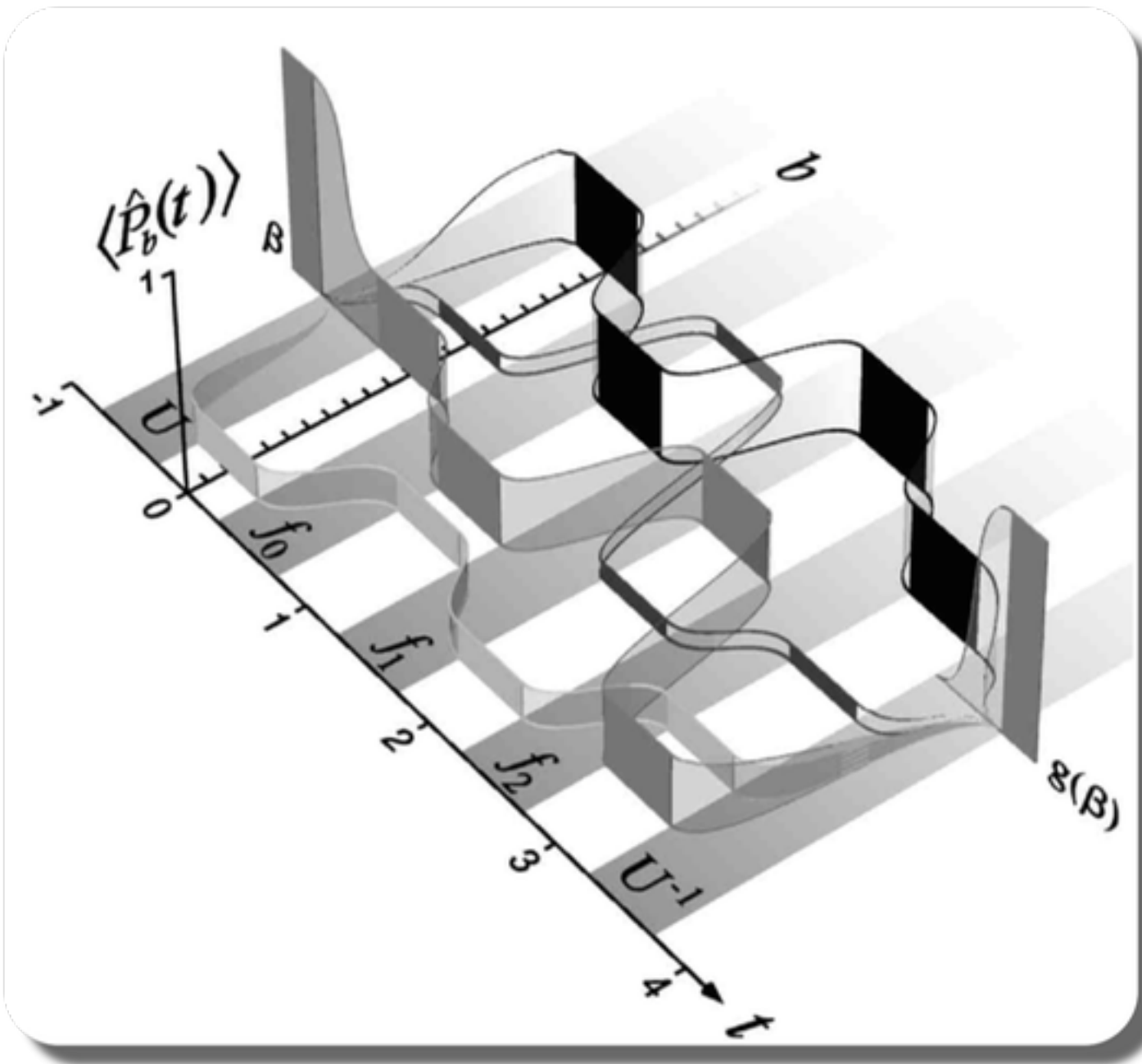
What above had been proved in the most stable way: theorems. What is the effect of the quantum superposition of states over an entire Bottling Control, composed of so many subsystems, is a question whose answer is time consuming. To really understand what is going on, it is vital to apply the cartesian view about the necessity to clear our inner scenario before to acquire new ideas, finally perceiving unknown facts for what they are: facts. As an example, there is not a widespread comprehension that a logic gate switching does much more than satisfy all of the requirements of a branching (or its apparent opposite, the merging):

- 1. it is the living example of a bifurcation;
- 2. its inherent information flow, structures the Multiverse.

“...a logic gate switching does more than satisfy all of the requirements of a branching: it is the living example of a bifurcation”



▲ History of a computation, as seen by the classic perspective. b is a parameter whose value is referred to the time parameter t , and whose initial state is $b(0) = \beta$. A bidimensional graph represents correctly the occurring computation



Right side: history of a computation, as seen by the quantum perspective. A 2-D graph cannot fully represent it. It is replaced by an infinitely wider space, a 3-D including a 2-D slice which is the classic perspective. Here, the information flow structures the graph Topology

In 2001 these ideas were object of a deep mathematical insight by the physicist David Deutsch, Oxford University, at Oxford, United Kingdom, over the beneficial revolution started by Schroedinger in 1927 and continued by Everett in 1957. Further details in the PDF document below on right side. A document whose consultation is strongly recommended to Electronics and Instrumentation Maintenance Managers and Engineers. It looks at the common logic gates of the every day Electronics, as seen from the vantage point of the most modern Physics.

There, with the formalism and notation appearing in the couple of graphics above, the Author introduces his point of view, today one winning increasing support, quoted below:

“.....have explained the power of quantum computation in terms of ‘quantum parallelism’ (many classical computations occurring in parallel). However, if reality – which in this context is called the multiverse – is indeed literally quantum-mechanical, then it must have a great deal more structure than merely a collection of entities each resembling the universe of classical physics. For one thing, elements of such a collection would indeed be ‘parallel’: they would have no effect on each other, and would therefore not exhibit quantum interference. For another, a ‘universe’ is a global construct – say, the whole of space and its contents at a given time – but



▲ David Deutsch, physicist at Oxford University, founder of Quantum Computation

since quantum interactions are local, it must in the first instance be local physical systems, such as qubits, measuring instruments and observers, that are split into multiple copies, and this multiplicity must propagate across the multiverse at subluminal speeds. And for another, the Hilbert space structure of quantum states provides an infinity of ways of slicing up the multiverse into ‘universes’, each way corresponding to a choice of basis. This is reminiscent of the infinity of ways in which one can slice (‘foliate’) a spacetime into spacelike hypersurfaces in the general theory of relativity. Given such a foliation, the theory partitions physical quantities into those ‘within’ each of the hypersurfaces and those that relate hypersurfaces to each other. In this paper I shall sketch a somewhat analogous theory for a model of the multiverse. The quantum theory of computation is useful in this investigation because, as we shall see, the structure of the multiverse is determined by information flow, and the universality of computation ensures that by studying quantum computational networks it is possible to obtain results about information flow that must also hold for quantum systems in general. This approach was used (...) to analyse information flow in the presence of entanglement.

In that analysis, as in this one, no quantitative definition of information is required; the following two qualitative properties suffice:

- **Property 1:** A physical system S contains information about a parameter b if (though not necessarily only if) the probability of some outcome of some measurement on S alone depends on b.
- **Property 2:** A physical system S contains no information about b if (and for present purposes we need not take a position about ‘only if’) there exists a complete description of S that is independent of b.

(...) an entity S qualifies as a ‘physical system’ if (but not necessarily only if) it is possible to store information in S and later to retrieve it. That is to say, it must be possible to cause S to satisfy the condition of Property 1 for containing information about some parameter b. It is implicit in this, and in Properties 1 and 2, that b must be capable of taking more than one possible value, so there must exist some suitable sense in which if S contained different information it would still be the same physical system. This condition raises interesting questions about the counter- factual nature of information which it will not be necessary to address here. It is also necessary that S be identifiable as the same system over time. This is particularly straightforward if S is causally autonomous – that is to say, if its evolution depends on nothing outside itself.”

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David Deutsch

The Structure of the Multiverse



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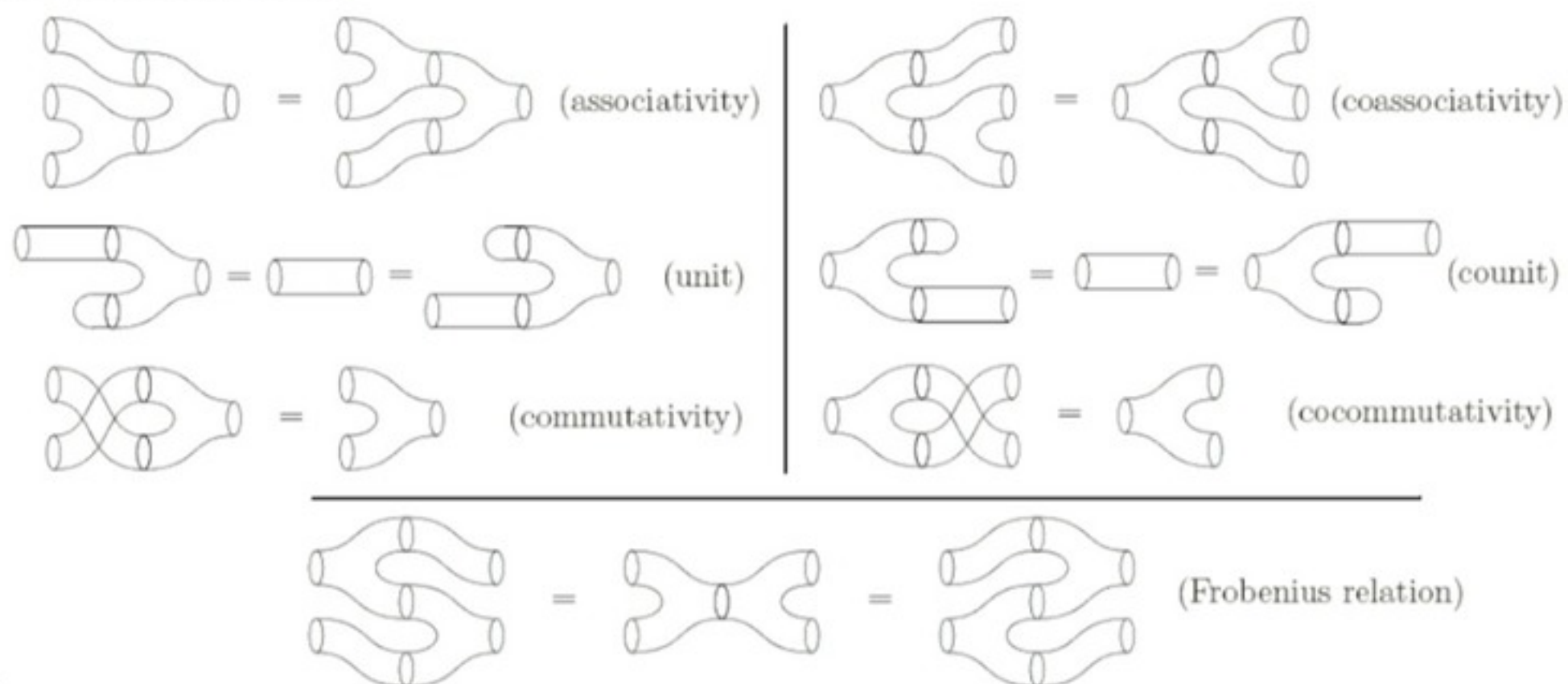
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Generators for 2Cob

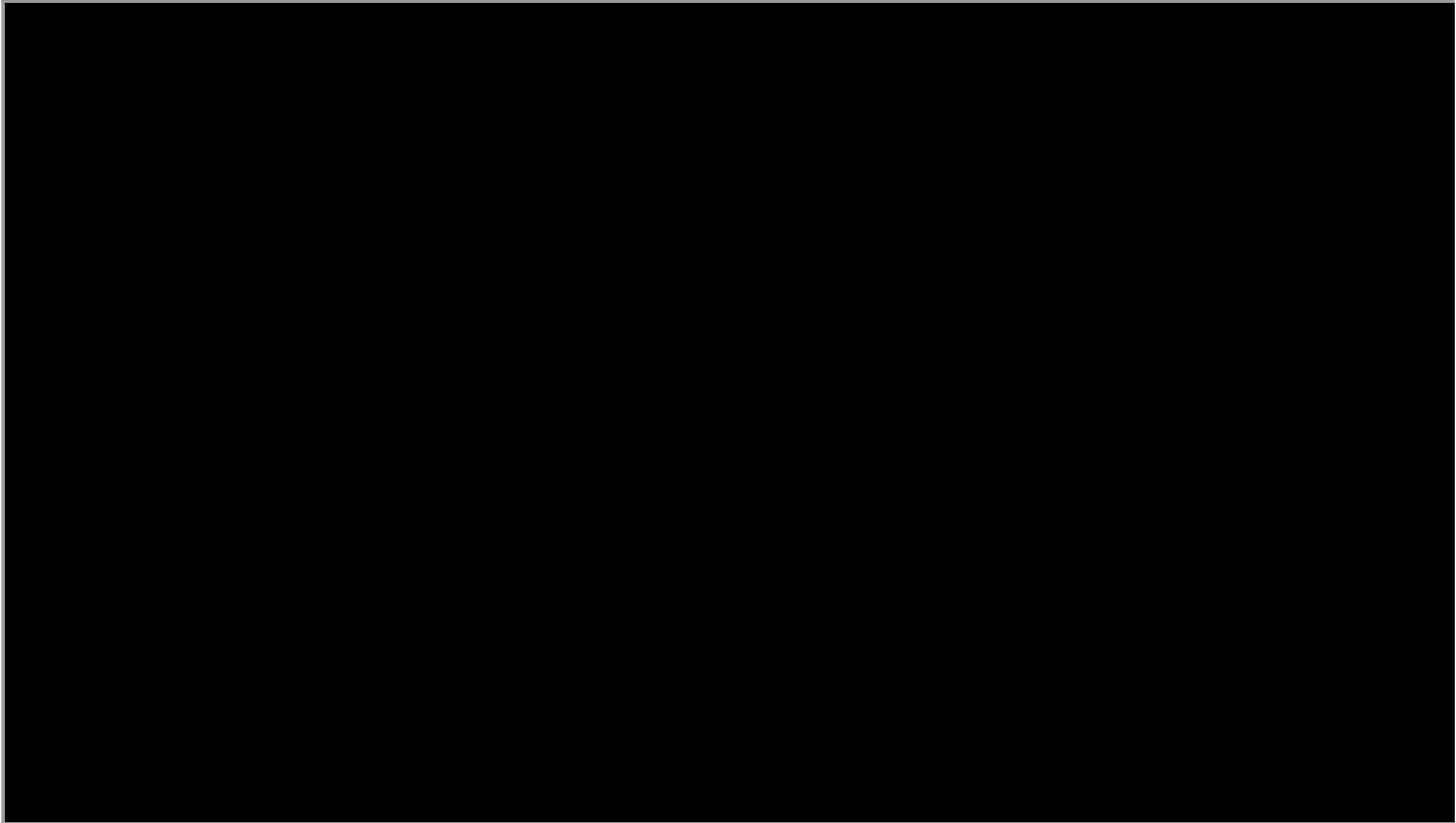


Relations in 2Cob



▲ Cobordism basic generators and relations allow to sight part of the rational in the words pronounced above by David Deutsch. The basic bifurcations and interferences allow and satisfy a wide spectra of mathematical relations. An immediate direct step from the Topology at the Quantum level to the Quantum Computation

Readers may infer the rationale lying in the words pronounced above by David Deutsch also by cobordism. Cobordism basic generators and relations allow to sight basic examples of bifurcations and interferences, satisfying a wide spectra of mathematical relations. A direct step from the Topology at the Quantum level to the Quantum Computation application. Unfortunately, further insights and consequences of the fact that a physical system change of state *is* a computation, as we'll see in the following, are today still mainly deepened by the Quantum Computation Departments of the worldwide Physics Departments.



Superconduction

The world is Quantum. At all scales

A dated objection to the idea of reality we are introducing, affirms that these phenomena, Quantum phenomena, really exist but their domain of application is limited to what we'll never see. The subatomic scale of distances where no technological application exists. This idea is obsolete. Try to board on the magnetic levitation trains of Shanghai in China or Muenchen, in Germany, and *you'll be personally moved by a Quantum phenomena.*

Festo® presents in the following video its own recent applications of superconduction for the Industrial Automation:

▲ Knowing how to encounter the way, the World we live shows its true nature: it is Quantum at all scales, and not only in the subatomic. This video authored by Festo® is devoted to a technological application of Industrial Automation

The ever changing fabric of space

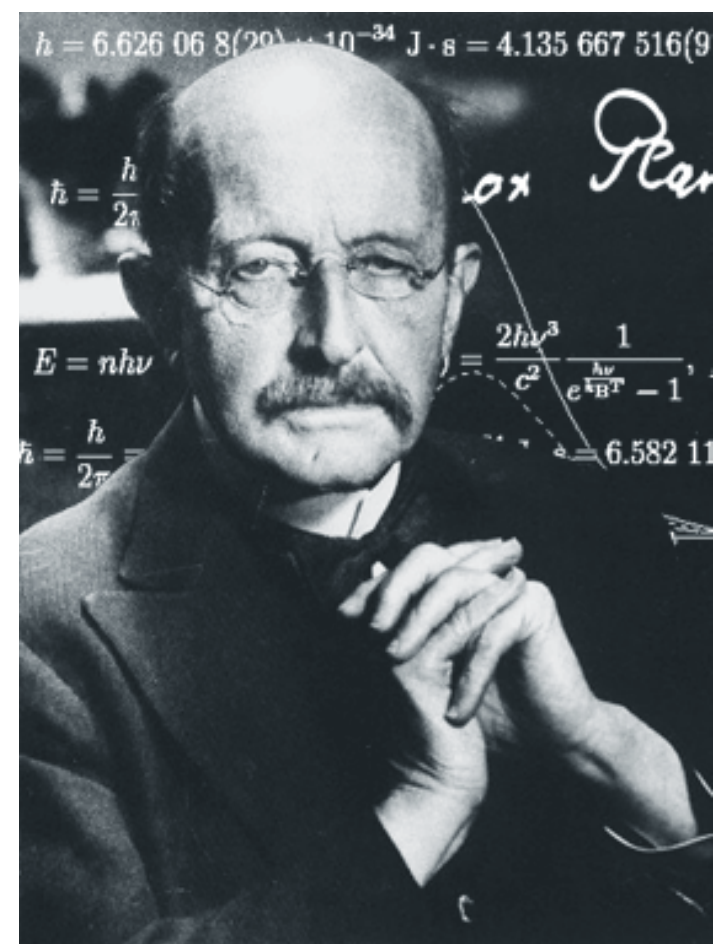
The classic Principle of Superposition hold considered valid during the twentieth century but, in the meantime, a row of experimental and theoretical discoveries changed the panorama. It was established that the subatomic arena where interactions happens has a *multiply connected space*, say a foam-like character completely different than the popular Euclidean spatial image where the angles between perpendicular axes are 90°. More, a spacetime whose dimension is not 4, as imagined more than one century ago, rather 10 or 11.

The figure and video below, illustrate what yet in 1973 was known to be close to reality.

It is generally believed that the picture of spacetime as a manifold \mathcal{M} locally modelled on the flat 4-dimensional Minkowski space described in the start of this page, should break down at very short distances of the order of the named *Planck length* λ whose numeric derives by the fundamental constants of gravity G , light speed c and Planck \hbar :

$$\lambda = (G \hbar / c^3)^{1/2} \sim 1.6 \times 10^{-33} \text{ cm}$$

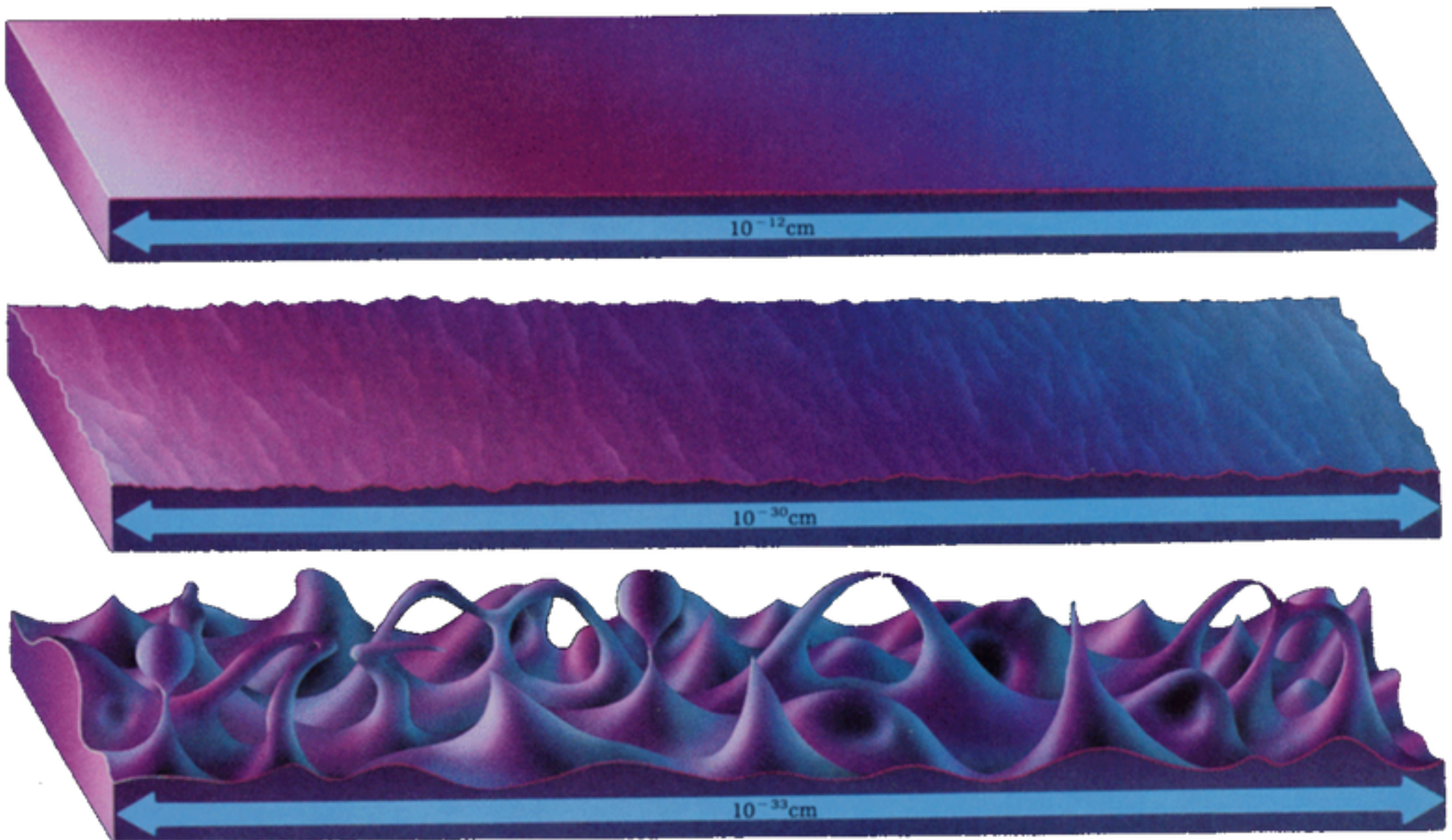
Space-time, so smooth and regular as it appears us, is on the opposite extremely rich of details at scales smaller than ours. Scales which are the arena for all of the Events. An intimate complexity of the structure, evident when closely looking the mechanical or electrical behaviour of the Systems at our scale of dimension, is embedded in the Topology of the space-time.



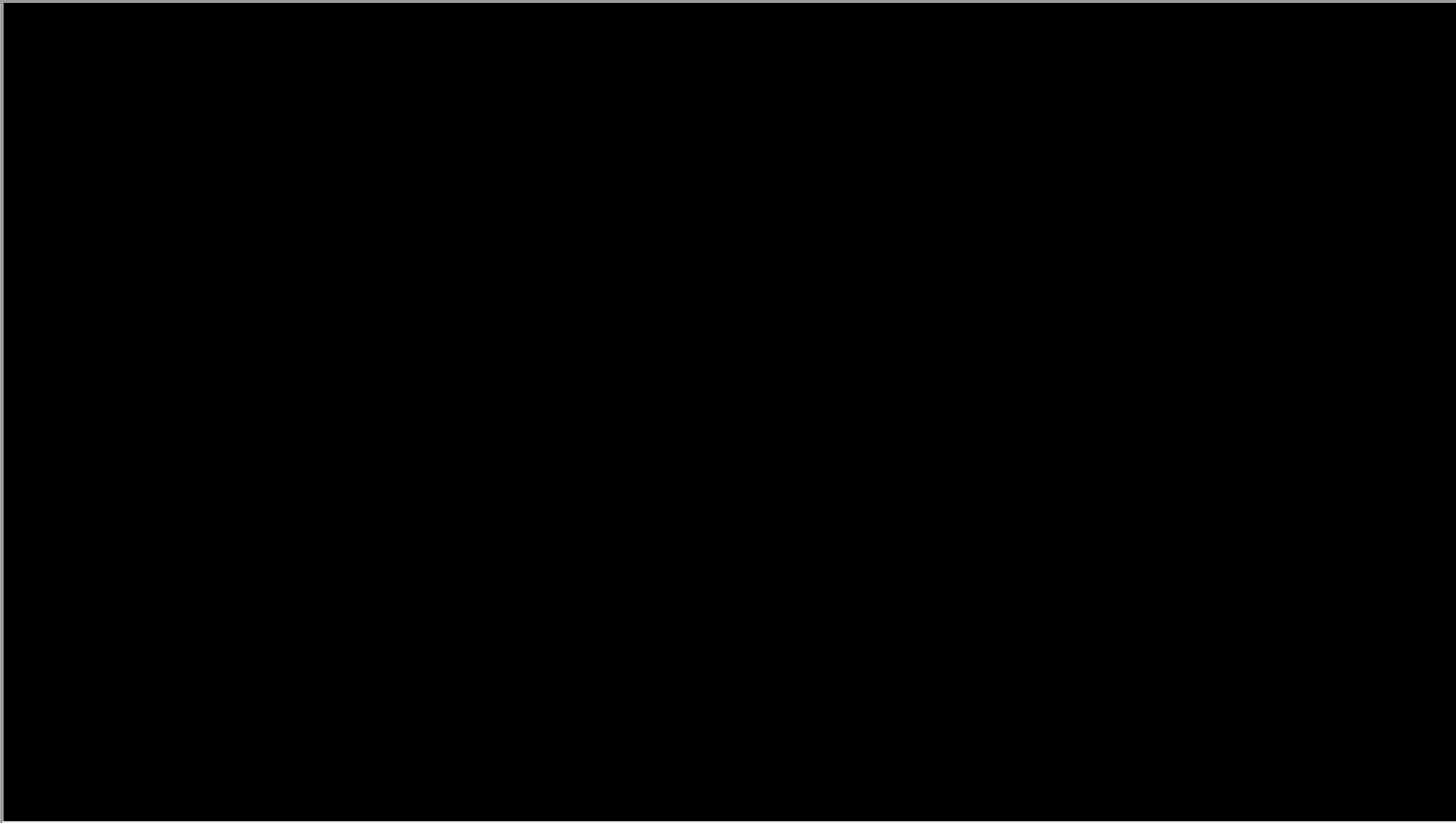
▲ **Max Planck, the first discoverer of Quantum Mechanics. He is the one who, first in the humanity, conceived that a**

Also, we have to consider that in the prior RLC circuit example, human normal sensibility to Events is limited to those whose duration is > 10 ms. It is surely possible to detect also Events much shorter, like powerful strobo flashes, but only because of the artificial technical solution discharging tens of Joule of electromagnetic energy along only $(0.1 - 0.3)$ ms. As a matter of fact, a LED diode illuminated along that same range of times, should be undetected.

pendulum could not be oscillating continuously, rather step-by-step



▲ The structure of the inner space is foam-like and constantly changing shape. We perceive all this only by mean of effects whose causes can be inferred by what is visible in our macro-scale. Matter and radiation have a size close to the micro-scale, and that's why they follow those rules. Non-linearity along measurement is artificially 'added', an effect of perspective due to the approximate theories. The universal superposition is linear



But, in the framework of the technical arrangement we adopted before to power the supposedly-linear RLC circuit, and considering that frequency and period are inversely proportional, then:

- increasing until 750 GHz the frequency of the signal;
- simultaneously monitoring the effects by an oscilloscope;

we have instrumentally zoomed ~75 billions of times toward the microscale.

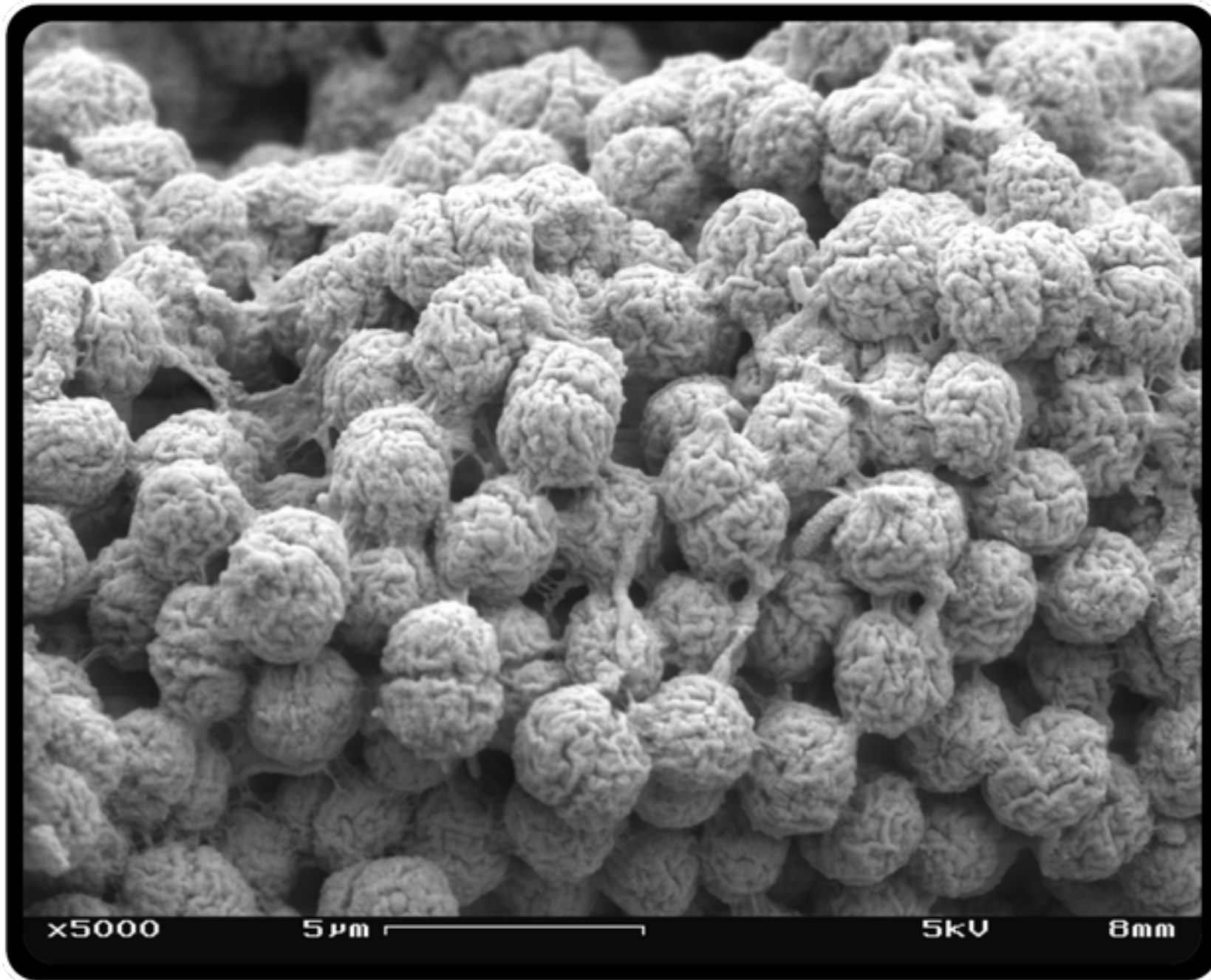
Along the 70’s Quantum Mechanics evolved in a quite different point of view named String Theory. It was then affected by several “Rube-Goldberg machine” problems. An amount of *ad-hoc* assumptions necessary to let the theory have explanatory power with respect to the zoo of newly discovered particles, constantly enriching itself of new entries deriving by new experimental discoveries. Discoveries made thanks to the Accelerators: humanity’s greatest and most precise measurement instruments of: position, time, electric charge, spin, energy, etc.

$$\begin{aligned} \text{Given a Time base } 750 \text{ Ghz} &= \\ &= 1.3 \text{ picosecond} \\ &= 0.000\,000\,000\,0013 \text{ second} \end{aligned}$$

what is the equivalent distance covered by light ?

$$\begin{aligned} \text{Equivalent spatial displacement} \\ x = c \, t &= 400 \text{ nanometer} \\ &= 0.000\,000\,4 \text{ meter} \end{aligned}$$

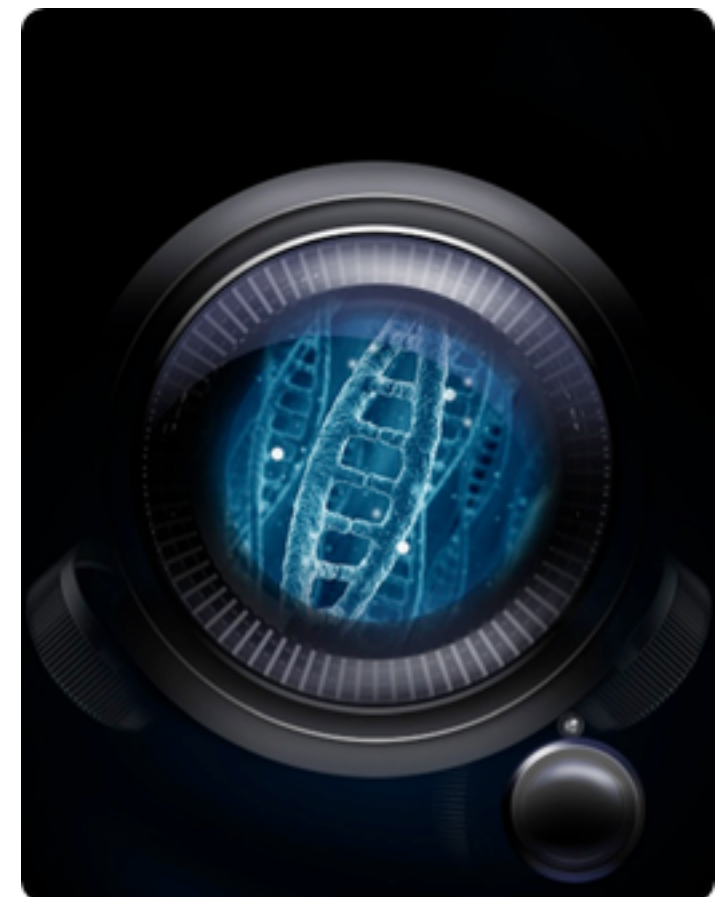
On left side: a scanning electron microscope image of a colony of algae. In the bottom indicated the reference scale of 5 micrometer. The small white coloured details in the image are the clouds of electrons around atoms of Ca, C, N, O and H. A signal whose frequency is 750 GHz has an equivalent spatial



displacement of 400 nanometers, say six times smaller than the individual algae diameter



Our own observation of an unexpectedly complex behaviour of the RLC serie resonant circuit, in some way resembles and gives an idea of the difficulty of interpretation of the results of collisions, where some of the *byproducts* live one million of times less than the 1.3 picosecond pulses of our Signal Generator set at 750 GHz signals.



More than explanatory power

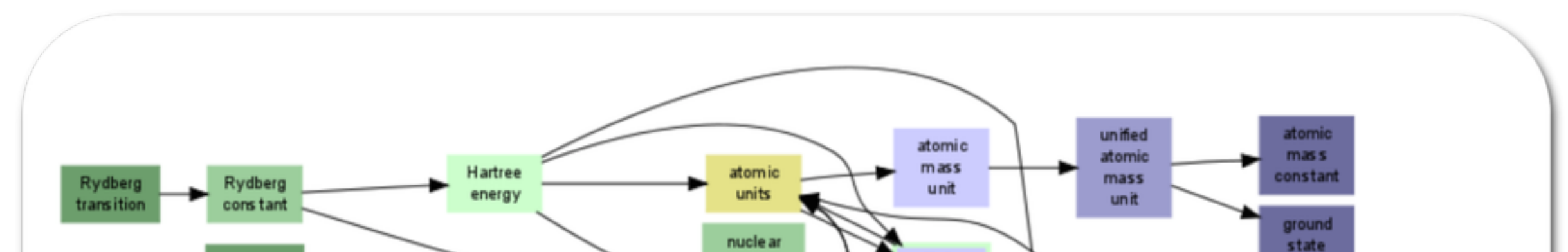
Virtual particles, positrons,...? One more time we stress the fact all what precedes and follows cannot be dismissed like ...*theory*, rather those interpretations of facts and theories which also let the industrial world all around us exist and be as productive as we know it really is. A direct feeling of this point may be perceived by the image below, originating by the international official body of Chemistry, the International Union of Pure and Applied Chemistry (IUPAC).

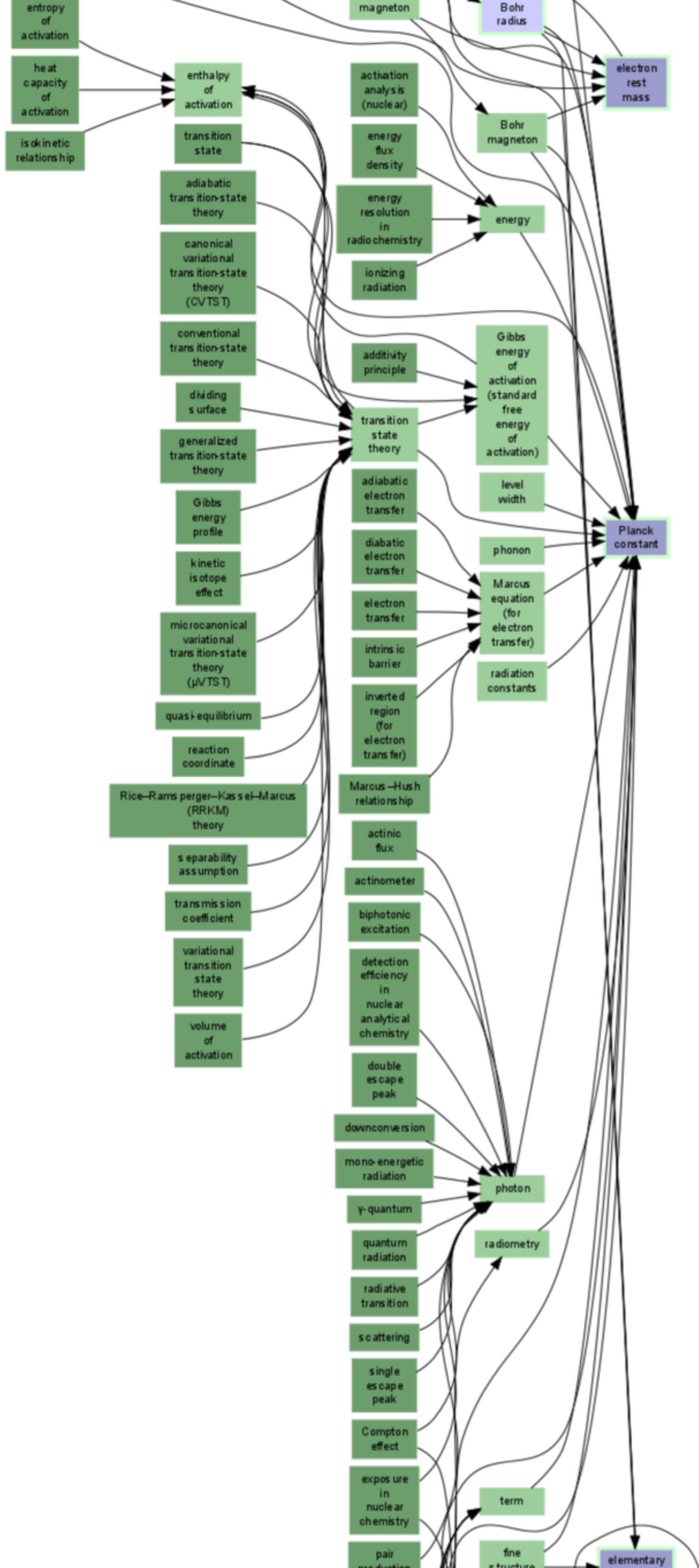
It shows the many interrelations existing between a few fundamental physical constants, like the Planck's:

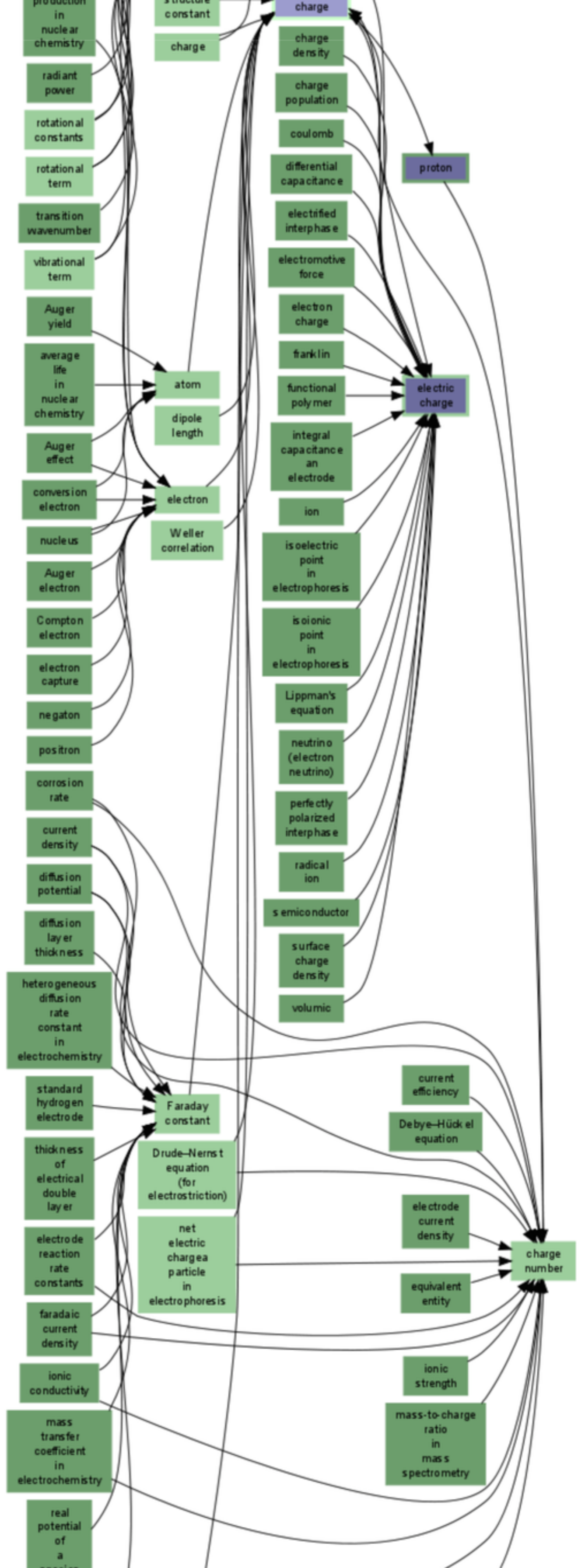
$$\hbar = h / 2 \pi$$

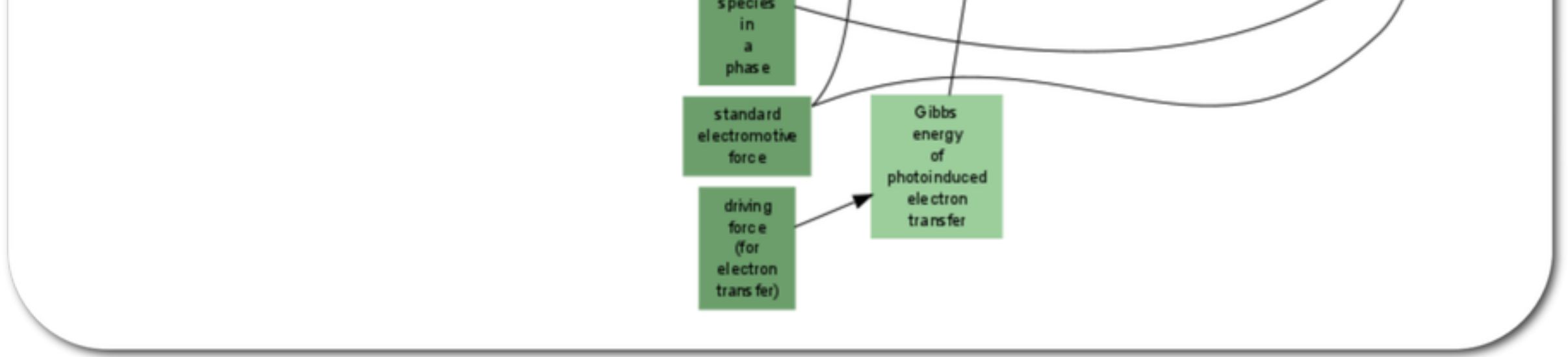
▲ **Zooming the micro scale. Reality is pinpointed by what is smaller than our dimension, for our own scale is composed by that subscale, and not vice versa**

the electron charge or the electron rest mass and tens of other physical phenomenons or chemical processes. Relations to events interesting objects much closer to the human space-time-energy scale we perceive directly. A trivial example, the evaporation of the boiling water in a beaker. Visibly, these are related each other by mean of those constants. Theories built over these constants offer much more than explanatory power with respect to observed behaviours and facts. They allow preemptive capabilities, so to know what has to be our expectation about the result of a process still not accomplished, a future process. The industrial terminology owns a definition for these preemptive capabilities: *design*.









▲ Theories built over a few fundamental physical constants offer much more than explanatory power for the observed facts. They allow preemptive capabilities, as an example, to know what has to be our expectation about the result of a process still not accomplished, a future process (credit A. D. McNaught, A. Wilkinson, 2006)

The shape of the inner space

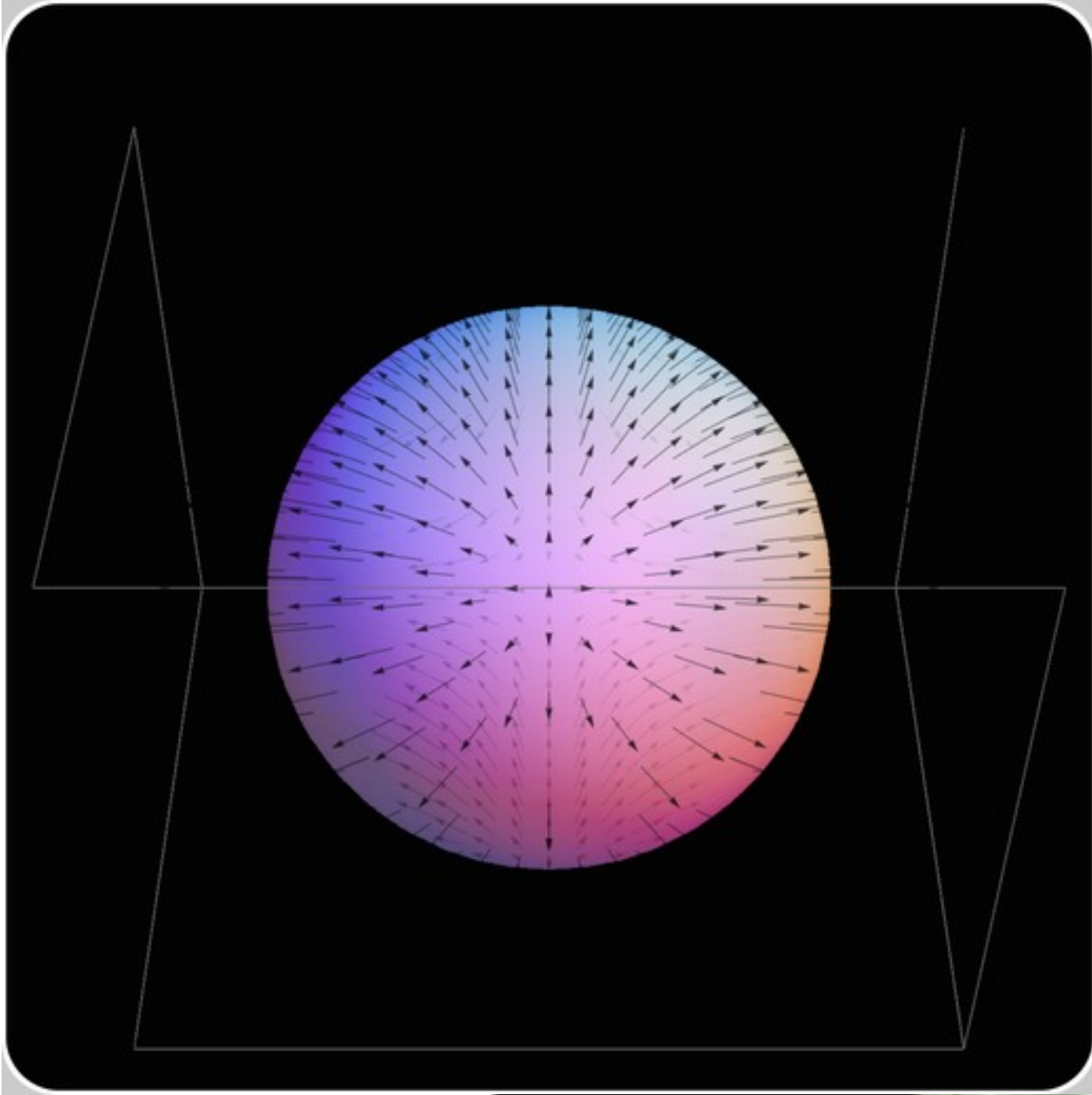
In 1953 the mathematician Eugenio Calabi was searching for a flat complex topology. His studies completely disconnected by the simultaneous physicists' investigations and the same term *String Theory* still to be coined. Calabi conjectured that starting with the case of one



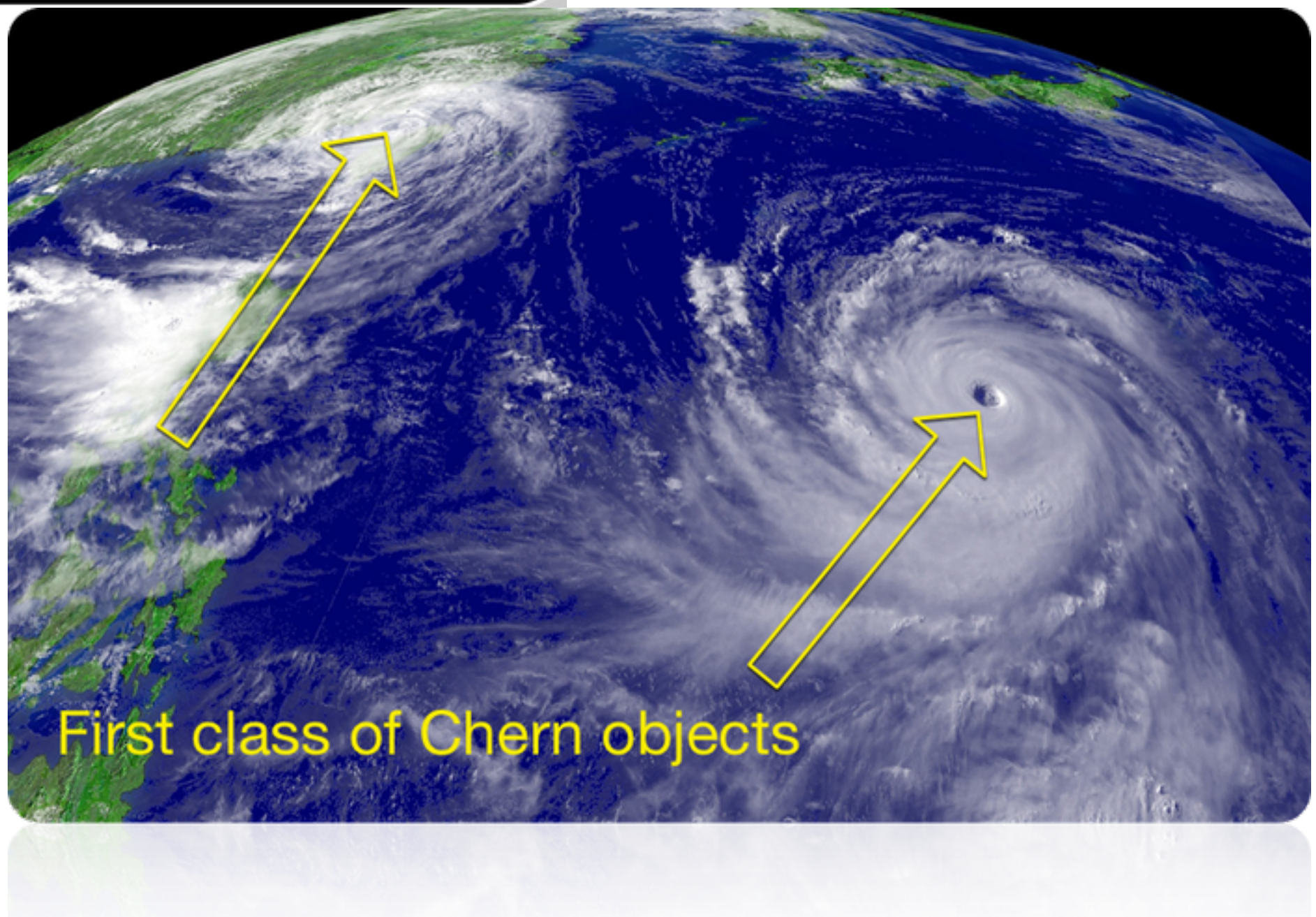
▲ We suggest the vision of this 3D animation full screen, High Definition and possibly wide bandwidth

complex dimension and two real dimensions, if the general Topology has average curvature zero, then it is possible to encounter a geometry (or, metric) where the curvature is zero everywhere. For dimensions superior to these, his conjecture refers to Ricci curvature and the condition of average Ricci curvature zero is replaced by the condition of first Chern class being zero. He considered that if the topologic condition of first Chern class zero is met, then it exists a Kaehler metric with zero Ricci curvature. In 1973 the mathematician Shing-Tung Yau after years trying to disprove Calabi's Conjecture, discovered the way to prove it was ...*correct* ! This discovery reached physicists who integrated it as new metric (a new Geometry) for the 6-dimensional inner space imagined existing in each one point of the 4-dimensional space-time we feel perceive directly (3-D space) or indirectly (1-D time). But, why to add dimensions, when to have less should apparently mean to have also less complications ? Several excellent reasons.

▲ An intuitive vectorial field: the radiuses getting out by the centre of a sphere

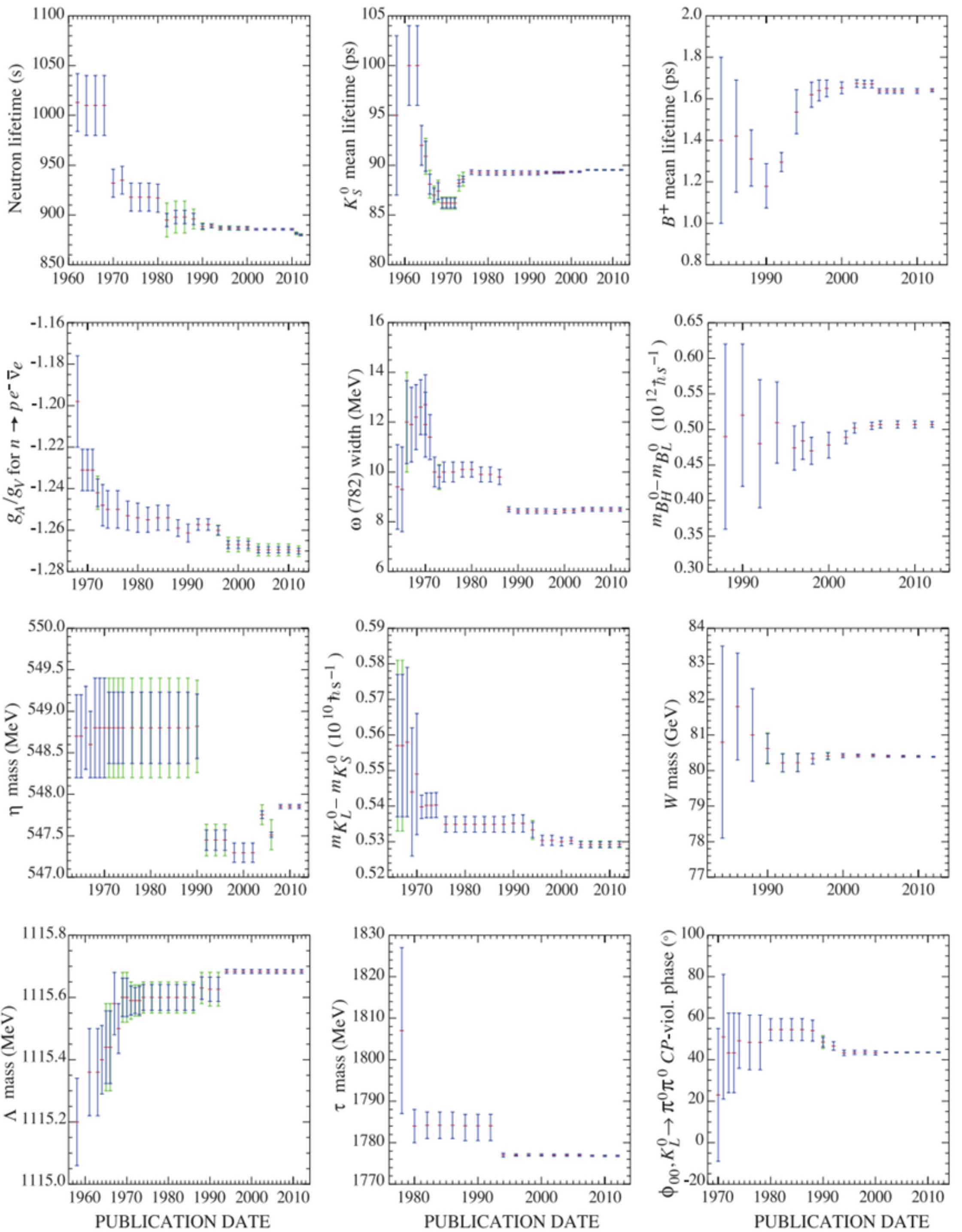


On right side: first class of Chern objects are places where flows in a vector field drop to zero. Hurricanes, a couple of them here visible in the Pacific Ocean and off the coast of Southern China, have central zones whose diameter range (2 - 280) km where flows in the wind vector fields drop to zero



First class of Chern objects

On left side: actually, seventeen elementary particles account for the known behaviour of the world, in the Standard Model (credit MissMJ, on data by J. Beringer *et al.*, Particle Data Group, Lawrence Berkeley National Laboratory)



▲ Fifty years of progress. Progressive reduction along past fifty years of the uncertainty in the determination of the mass, expressed in eV, and lifetimes of twelve particles [credit J. Beringer et al., Particle Data Group, Phys. Rev. D86, 010001 (2012)]

proceed forward in the knowledge, this has effects also out of the experimental ambit.

Experimental results compared with theories, implying e.g., the refutation of some theories’ underlying assumptions and/or confirmation of other theories predictions, in what since three centuries is the process of scientific discovery. An example of this in the twelve graphs above (credit J. Beringer et al., Particle Data Group, Lawrence Berkeley National Laboratory) quantifying the progressive reduction of the uncertainty in the determination of the Mass (expressed in eV) and lifetimes of twelve particles, along past fifty years. Uncertainties expressed as blue colour vertical error bars, around the weighted mean values of experimental origin. That’s why the new geometric descriptions adding six independent degrees of freedom, in the form of six additional spatial axes, were welcome. We are speaking of stringlike particle, objects having extension in only one dimension. In superstring theory the strings are exceedingly small and move through a 10- or 11-dimensional analogue of space and time (see graphic below, immediately after the video). In the diagram, the time evolution is along the vertical axis, increasing from the bottom to the top. Closed strings, also represented as coloured closed loops, enter from the bottom and leave on the top. The topological structure of a world sheet describing these quantum-mechanical interactions is like that of a doughnut with an arbitrary number of holes.

Interference

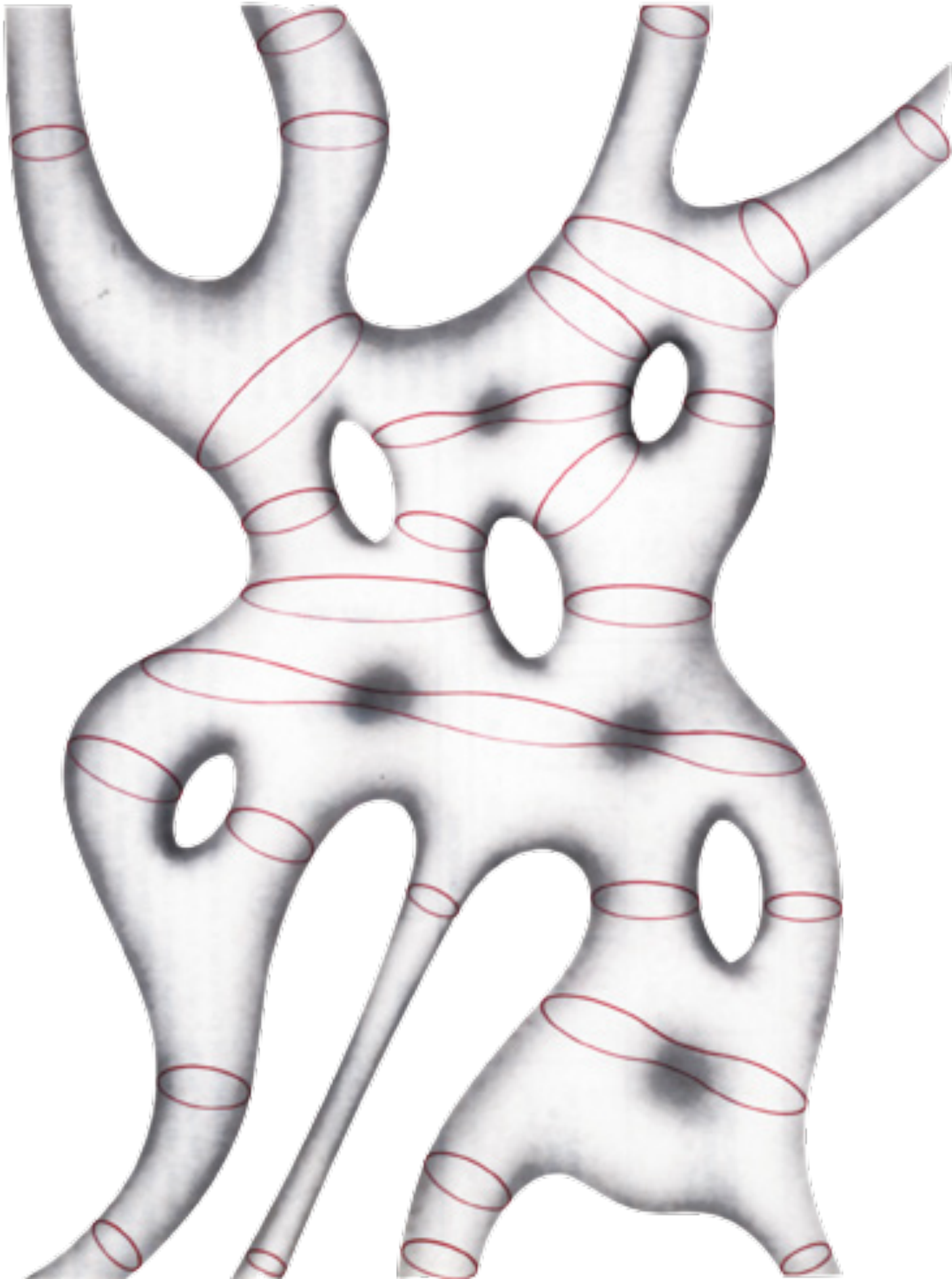
The closed strings sweep out world sheets that are deformed cylinders, topologic equivalents of a cylinder. When two strings collide, they join to form a third string: two cylinders form a third cylinder. This is the fine detail allowed by the most modern point of view, what was since centuries named interference.

Bifurcation

When strings split apart and rejoin, a hole is left in the world sheet. In the quantum calculations all possible splittings and joinings between an initial state of strings and a final state must be considered. This way recalling the basic idea of Feynman’s sum over histories.

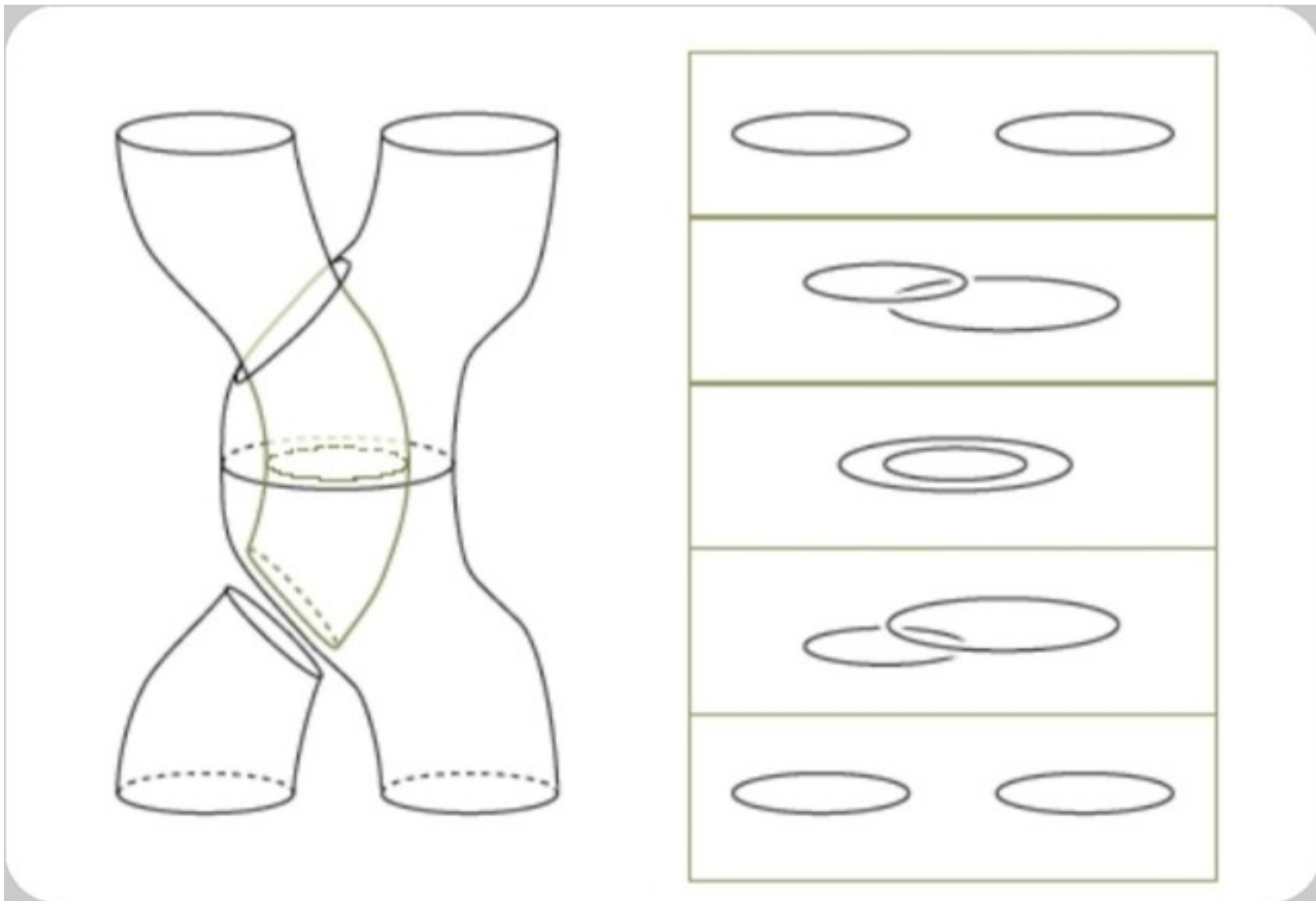
Loopbraids

And, one more time, we know the Reader feeling about all this. A question, a fundamental question: if all this is happening, *if really there are so many coexisting superposed objects, where are them ?* One of the many correct answers to this question has been provided by the developement of that branch of Mathematics originally named Analysis Situs (today, Topology), founded over one century ago by the great Henri Poincare’. *Loopbraids* like the one visible below, illustrate one of the ways to the coexistence of common material objects in the same higher-dimensional space. Each one of the objects in the figure below is not interfering with the other. The presence of the other totally unnoticed due to the topologic genus (the hole) present in one of them. Is it there really so much space in the microscale, so to host a loopbraid like this, with many others encased one into each other genus ? Remember Minkowski’s discovery of 1908: each one dot of 3-dimensional space is infinitely extended in the 4-dimensional space.



▲ Time evolution of a small section of a world sheet. Bifurcations and interferences, constantly happening at the finest scales, hint to a superposition. A superposition whose components constantly coexist *at least* in all of possible values allowed by the fundamental physical constants and by the physical laws established with these constants (image credit M. B. Green, 1986)

We'll see in the following the convergence of theory and experimental results toward at least ten dimensions.



▲ Loopbraids like the one visible here, illustrate in what a way it is possible the coexistence of common material objects in the same higher-dimensional space. Each one of the objects not interfering with the other. The presence of the other totally unnoticed due to the topologic *genus* (the hole) present in one of them. This figure hints to a topologic complexity much higher than the precedent, and much closer to the real geometry. A world made of pipes (or, strings or membranes) and *not a geometry made of pipes in the space*. In the modern scenario, dimensionality is a feature of the strings or pipes, and there is no one spatial-immersion at all. Space, exactly as recently happened to time, relegated to a secondary concept rather than a fundamental. Strings are the fine texture of the world, without anything added

What an apparent shape for the new inner space is hinted by the video below (which can be freely downloaded here (<https://vimeo.com/81756249>)) where, on:

- left side, an individual 3-dimensional projection of a 6-dimensional Calabi-Yau manifold;
- right side, the shape of the physical space. The yellow colour lattice represents two of the four dimensions of the physical space-time we perceive, and in each intersection lies a compact 6-dimensional Calabi-Yau manifold, totalling nine space dimensions plus Time.

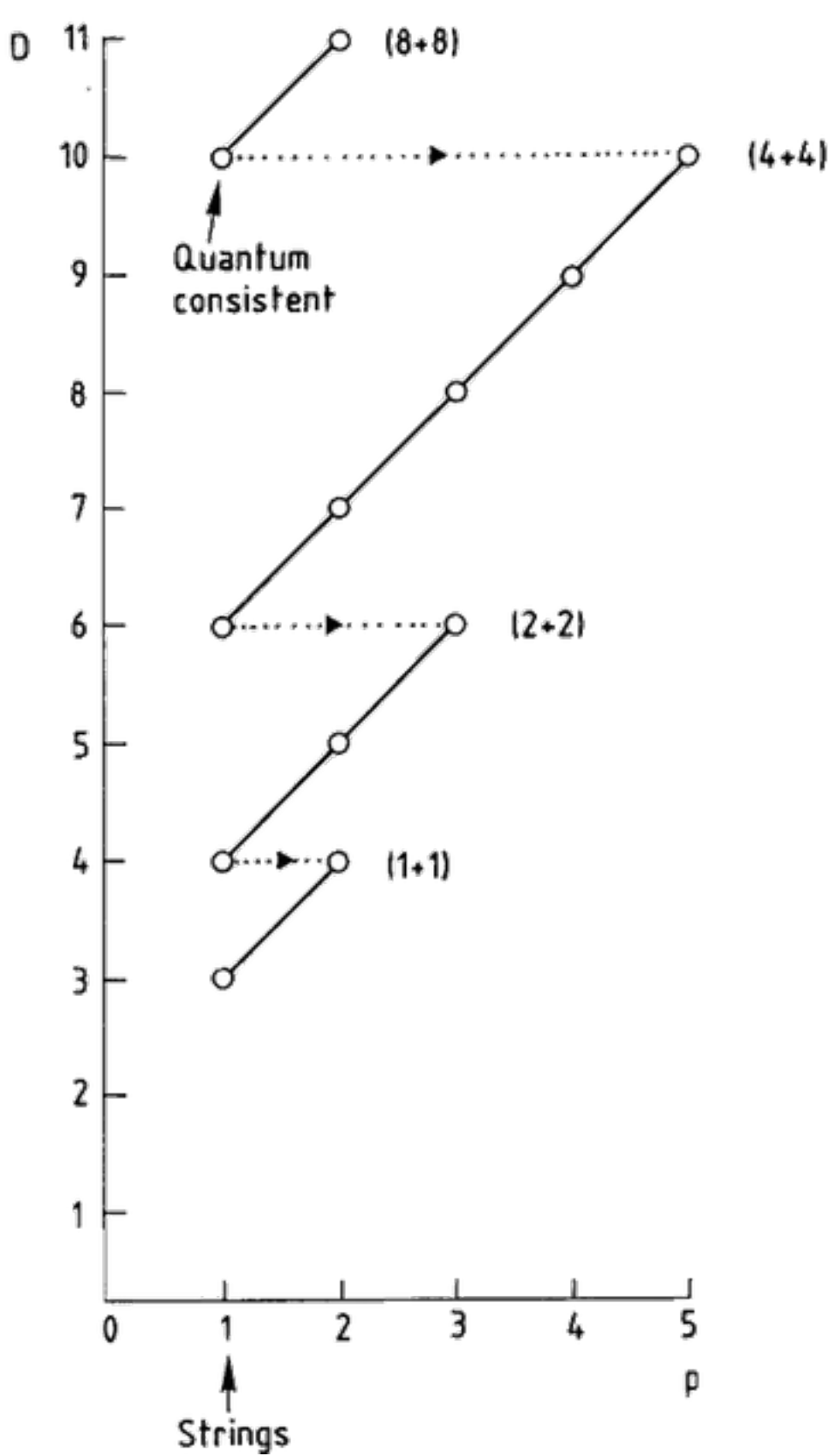
Key concept to such new scenario is the compactness of the 6-D manifold: in Geometry it is possible to have additional compact dimensions of infinite or finite size, lying in an infinitesimal space. The new category of geometric Calabi-Yau manifolds, allowed a rapid success of String Theory in terms of consistency with the experimental discoveries of accumulated along decades by the High Energy Physics (HEP). The objects of String Theory, namely are strings, unidimensional objects (1-D) like those depicted in the figure on right side, vibrating on tones and overtones. As an example, it was imagined that electrons were microscopic closed vibrating strings. String theorists, whose confidence was enforced by the high level of consistency of their logic construction with respect to Quantum Mechanics, were however feeling the still missing inclusion of the gravitational force. The last decisive step toward the unification of all known forces.

From String Theory to Membranes Theory

This unification came in 1995: we are living an epoch when the fundamental theory (the one holding all others as consequences), of all is no more String Theory. Rather, its successor M-Theory where the “M” means *Membranes*.

Extended objects with one or more compact spatial dimensions named *p-branes*, objects of p-dimensional spatial extent:

- 0-brane is a point particle;
- 1-brane is a string;
- 2-brane may be imagined the Ocean's surface, wrapping the Earth and propagating in the 4-D spacetime of the Solar System.

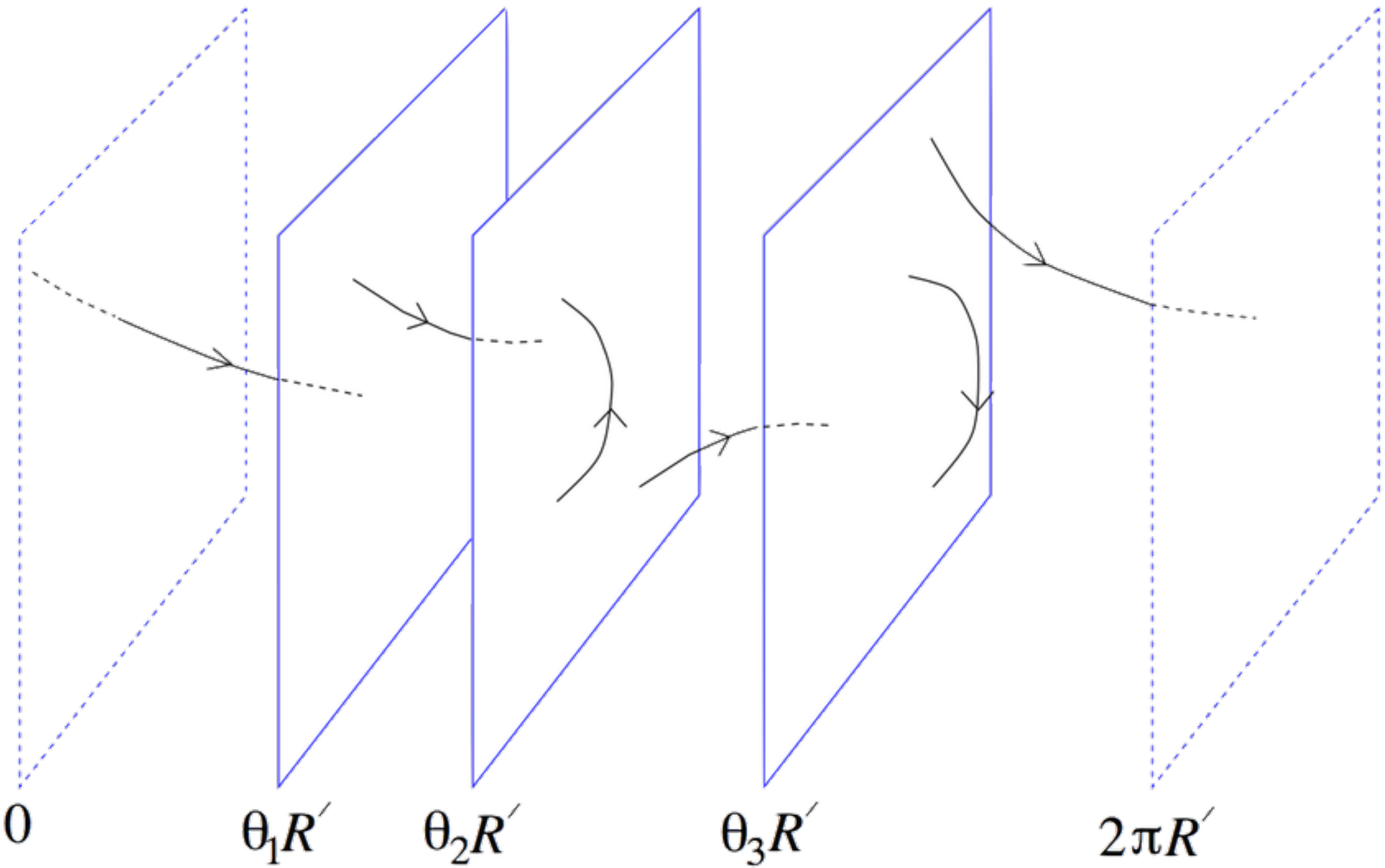


Describing a brane as an object propagating through a spacetime we'd be placing the spacetime on a primary, and the brane on a secondary footing. In the reality, the String Field Theory (M-theory) on the brane is the primary concept, whereas the spacetime is a derived concept. The graphic above on right side, shows the relation between dimensionality D and the dimensional class p of the membrane.

▲ **Relation between the total number D of spatial dimensions and the brane dimensional category p**

The history of a p-brane may be described mathematically by a map $\phi : \mathcal{W} \rightarrow \mathcal{M}$, where:

- \mathcal{W} is a reference (p + 1)-dimensional manifold;
- \mathcal{M} referred to as "target space", represents the spacetime through which the brane propagates (e.g. in the case of the Ocean, the tetradimensional spacetime);
- $\phi(\mathcal{W})$ is a "worldvolume", same meaning presented here.



▲ **Three D-branes at different positions, with various strings attached, representing particles different than gravitons (abridged by image C. Johnson, 2000)**

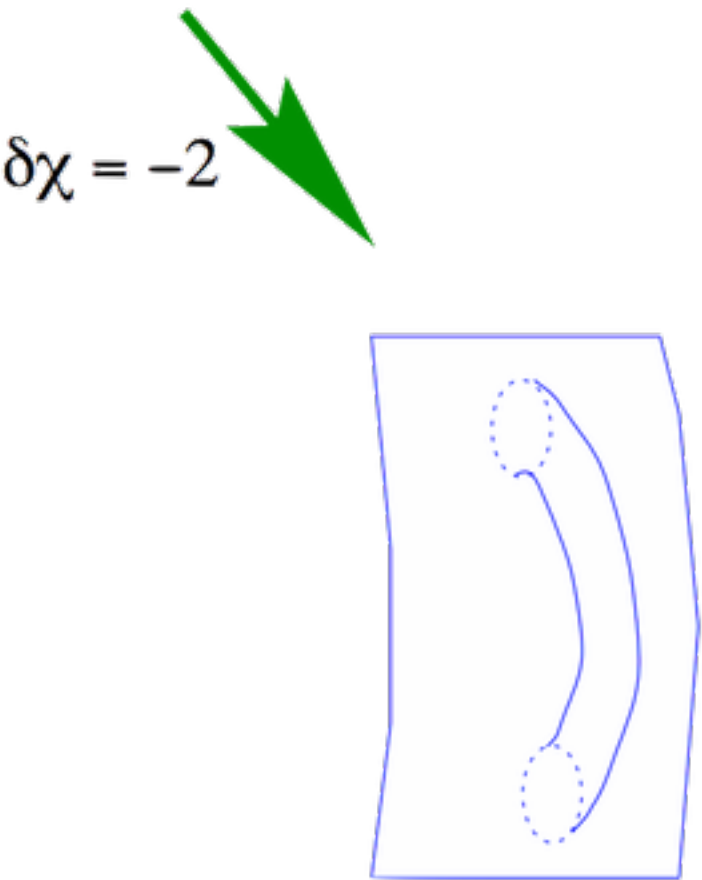
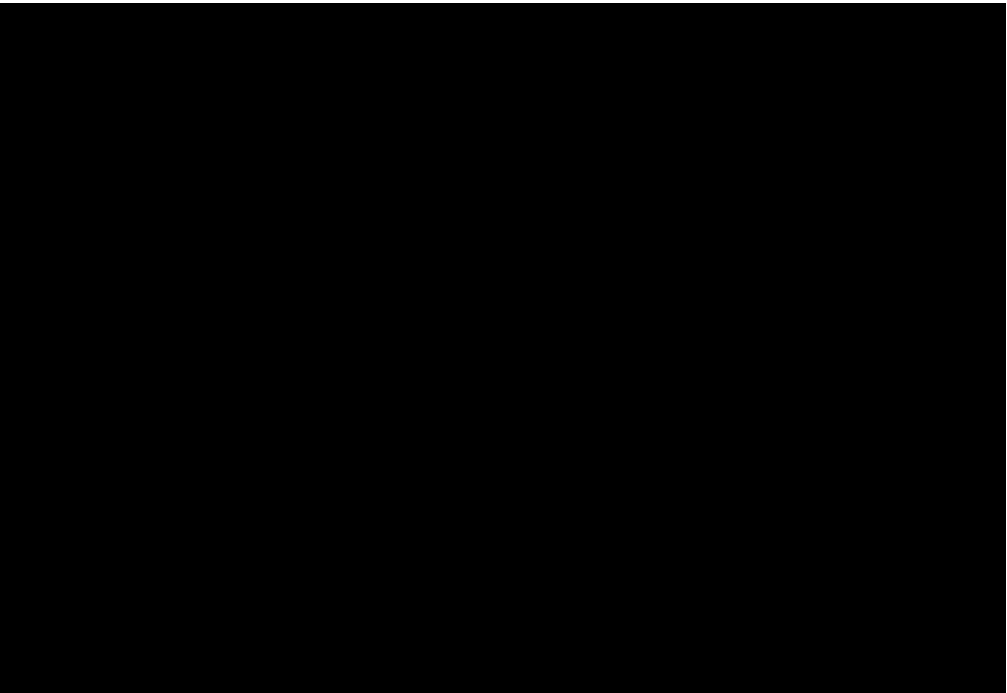
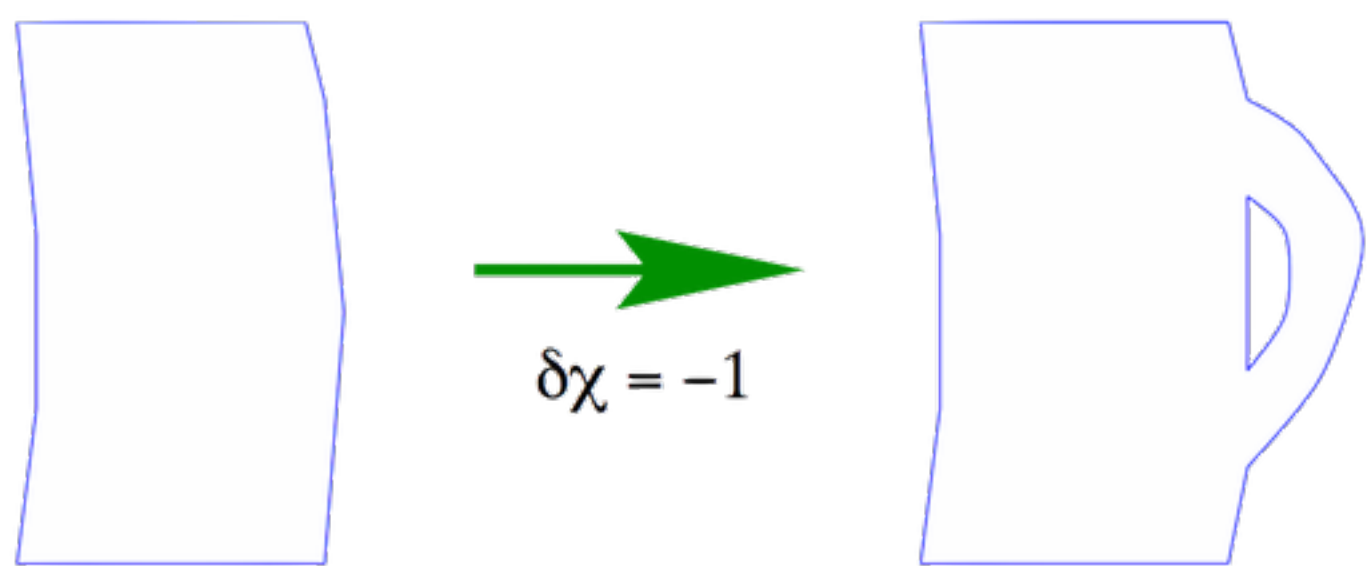
Membranes are elastic objects

Membranes, those of the everyday life, knowingly are elastic. Same way, also Branes are not static objects, rather dynamical: an example on left side shows how the worldsheet topology change due to emission and reabsorption of open and closed strings. The oscillations are sections of the normal bundle to $\phi(\mathcal{W}) \subset \mathcal{M}$ described by a (p + 1)-dimensional scalar field theory on the brane. All branes are elastic. But it is a fact that the torsion of some is such that let them be extremely rigid.

The video below, quite well represents a 3-dimensional elastic brane. It is a 4K Ultra High Definition video, meaning that:

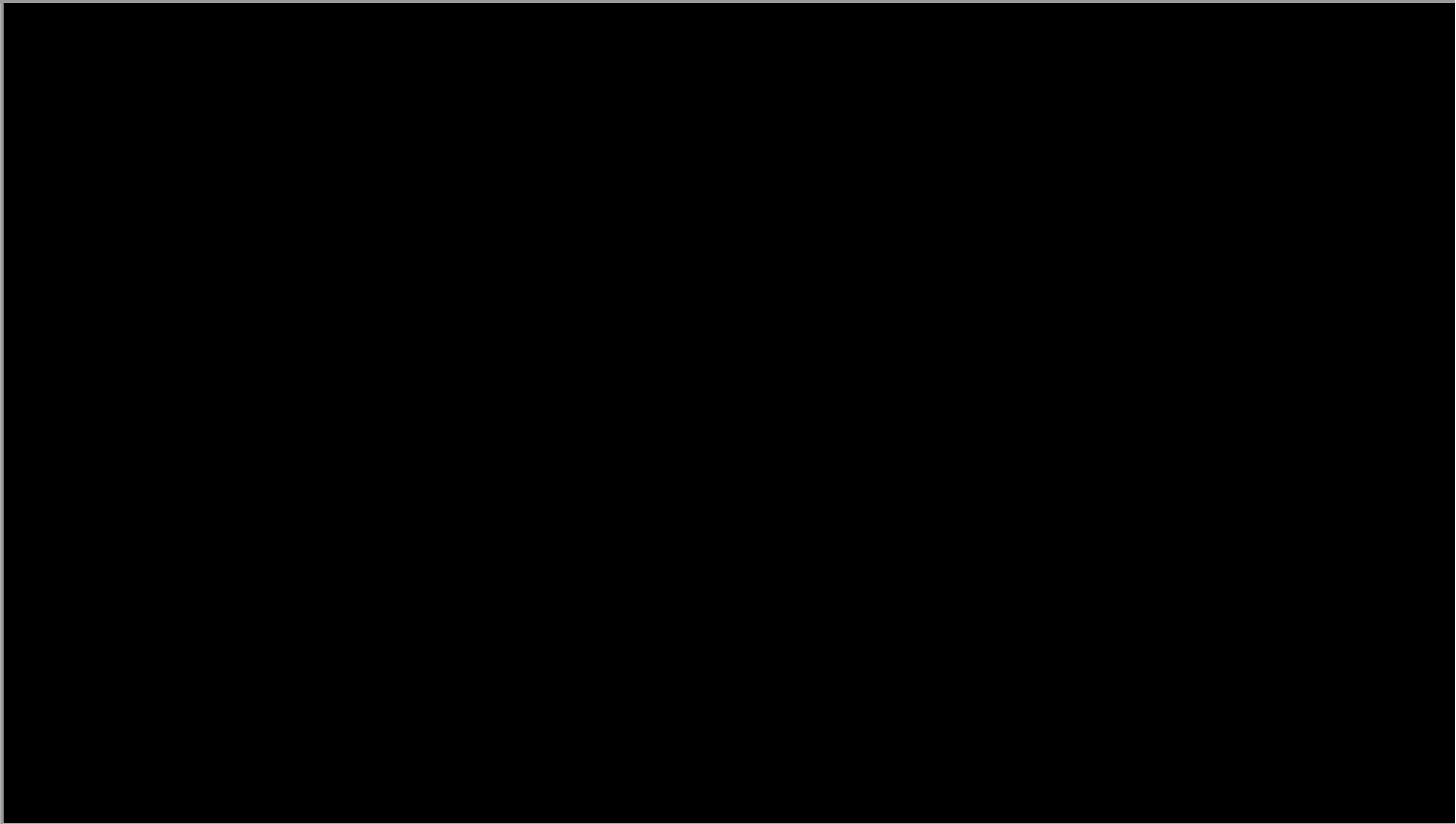
- due to its extremely high data rate, however streamed, a fibre optic connection to Internet is recommended;
- best seen in full screen.

On right side: worldsheet topology changes due to emission and reabsorption of open and closed strings (abridged by C. Johnson, 2000)

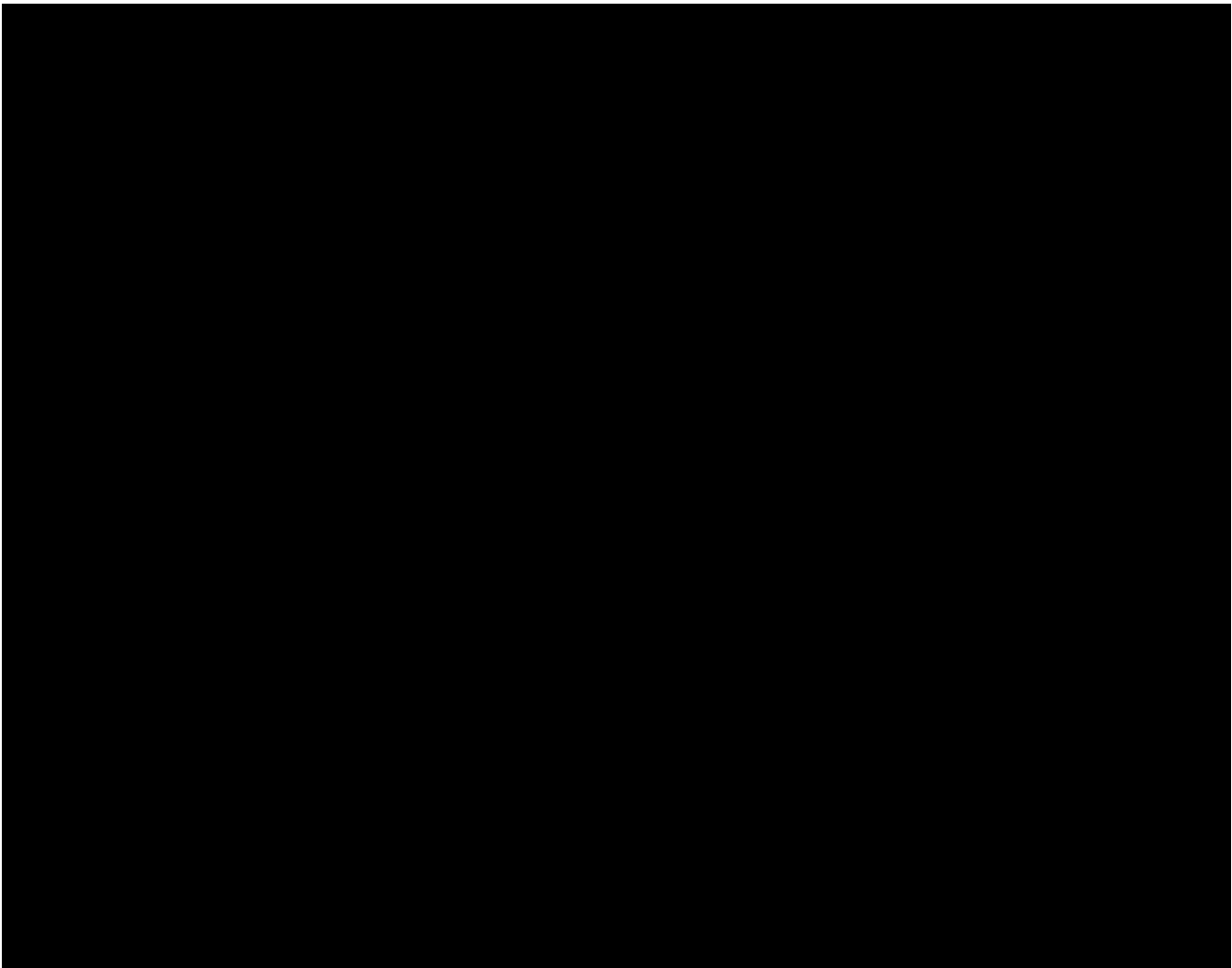


▲ (Mem)branes can be also extremely elastic.
The Ultra High Definition 4K video above
represents the concept (credit Quayola, 2013)

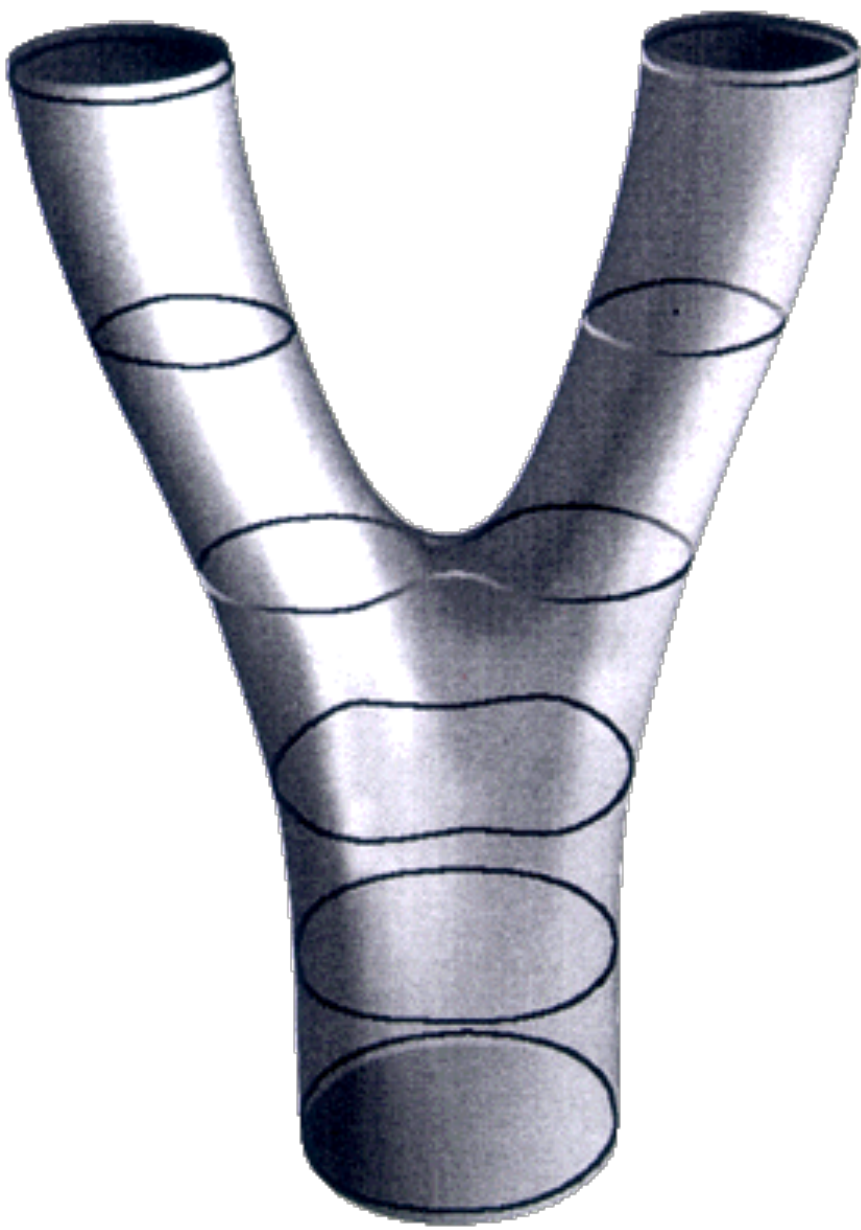
As additional *visual aid* to the comprehension of subjects whose full meaning is only mathematical, we recommend to see the video below, representing something whose shape is well imprinted in the mind of whoever. Taking as an example the Ocean of the Earth, the scalar field would represent the height of the waves and the Ocean’s surface may be imagined as a 2-brane wrapping the Earth and propagating in the tetradimensional spacetime of the Solar System. The D–brane is a dynamical object, and as such, feels the force of gravity. The tension of the brane controls its response to outside influences trying to make it change its shape.



An astounding relation exists between branes and the space we inhabit (abridged by footage credit NASA, *et. al.*). The video is here available for download. (<https://vimeo.com/86777498>)



A macroscopic change of the aspect of a common object, without any change of its Topology. Topology encodes the essential characteristics of spaces and of their relations



Left side: today a bifurcation is considered the effect of a change experienced by a 2-brane from one to another kind of topological variety. In the image the change in the amount of closed loops: below, a single particle and above a couple

Right side: the initial 1000 digits of π . The sequence, extending itself toward infinite, derives by the initial unique conditions existing in the *pocket* we inhabit. It is a local condition, a Universal but not Multiversal constant

These subjects are definitely out of the scope of these pages devoted to the fundamental role of the Measurement, as applied in the Electronic Inspectors. We'll simply outline the position reached during last twenty years. The underlying enormous amount of varieties of Calabi-Yau manifolds converges with others experimental and theoretical ideas, backing the a conjecture about the coexistence of a huge number of other *Environments* and new continously being nucleated. A process not particularly different than the nucleation of CO2 bubbles in the Carbonated Beverages. Also, a process whose physics is not particularly different than the nucleation of CO2 bubbles in the Carbonated Beverages. The term Environments here used as a synonymous of the classic terms: worlds or universes.

Other histories

However, the entire tree-like sequence of ramifications or branchings, interposed between Us and now and the common Origin, featured since the very start identical physical laws and values for the geometric, physical and chemical constants. But, this is probably not true for other branches. A bubble nucleated before or after our own, has a low probability to be founded over the same set of geometric, physical and chemical constants.

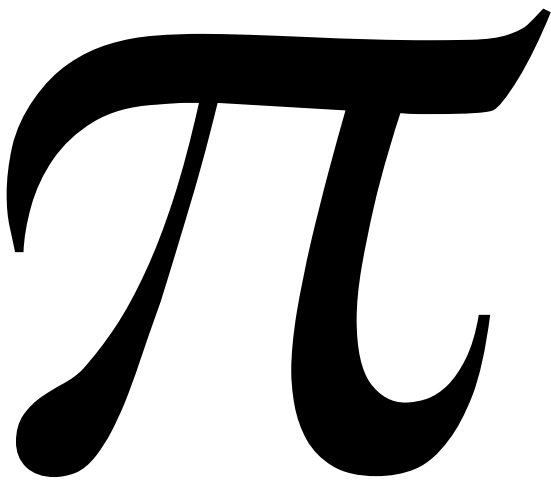
Environments where, as an example, some of the most basic axioms of the Arithmetic look different that what we know, so that:

- $1 < 0$
- $b \neq b$
- $a\ b \neq\ b\ a$
- $a\ (b + c) \neq\ a\ b + a\ c$
- $\pi \neq 3.14159265358979323.....$

and, built over such varieties of Mathematics are Physical Laws different than what we know, starting by the values of the fundamental physical constants.

So different that, as an example:

- gravitational $G \neq 6.67384 \times 10^{-11} \text{ m}^3 \text{ kg}^{-1} \text{ s}^{-2}$
- speed of light in vacuum $c \neq 299\ 792\ 458 \text{ m/s.}$



3.1415926535 89793

23846 26433 83279 50288 41971 69399
37510 58209 74944 59230 78164 06286
20899 86280 34825 34211 70679 82148
08651 32823 06647 09384 46095 50582
23172 53594 08128 48111 74502 84102
70193 85211 05559 64462 29489 54930
38196 44288 10975 66593 34461 28475
64823 37867 83165 27120 19091 45648
56692 34603 48610 45432 66482 13393
60726 02491 41273 72458 70066 06315
58817 48815 20920 96282 92540 91715
36436 78925 90360 01133 05305 48820
46652 13841 46951 94151 16094 33057
27036 57595 91953 09218 61173 81932
61179 31051 18548 07446 23799 62749
56735 18857 52724 89122 79381 83011
94912 98336 73362 44065 66430 86021
39494 63952 24737 19070 21798 60943
70277 05392 17176 29317 67523 84674
81846 76694 05132 00056 81271 45263
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58537 10507 92279 68925 89235 42019
95611 21290 21960 86403 44181 59813

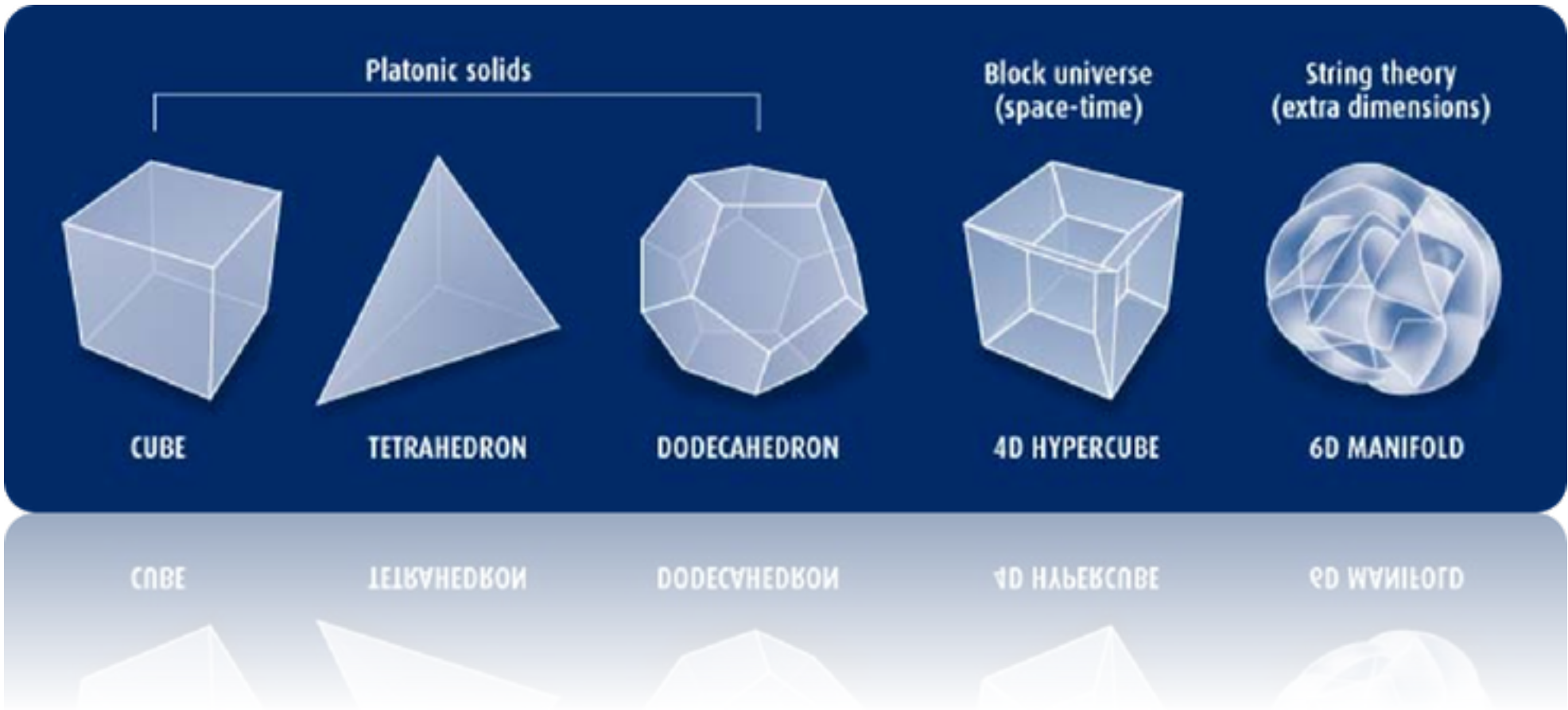
62977 47713 09960 51870 72113 49999
99837 29780 49951 05973 17328 16096
31859 50244 59455 34690 83026 42522
30825 33446 85035 26193 11881 71010
00313 78387 52886 58753 32083 81420
61717 76691 47303 59825 34904 28755
46873 11595 62863 88235 37875 93751
95778 18577 80532 17122 68066 13001
92787 66111 95909 21642 0198

Questioning ourselves about the meaning, the signification of a tree-like structure coexisting with our own but nearly disconnected, has to remember Hermann Minkowski's intuition of 1907.

The same breakthrough explained so well nearly 50 years later by Albert Einstein:

“A 4-dimensional space contains ∞ 3-dimensional spaces”

These spaces coexist and are different leaves of the foliation. The dimensionality of the space whose 3-dimensional leaves we, our machinery and devices are populating, is today object of intense theoretical and experimental investigations. An eufemistic way to say it is unknown. We saw above that the dimensionality D of the branes, ranges from 3 to 11. This implies on practice the coexistence of, at least, all of these String Field Theory varieties. A coexistence in branches of the Multiverse however rarely-interfering and nearly-parallel. On practice, other histories. As a matter of fact, some of the components of that complex superposition of *Signals* too rapidly dismissed to the rank of *Noise*, are Signals from those other branches. Signals deriving by the most common and generalized process in a Superposition: *interference*.



▲ Three thousands years of evolution of our ideas about space. Minkowski space-time followed the ancient conceptions. Since two decades a manifold with at least 6 hidden spatial dimensions, has replaced the reletivistic 4D hypercube (abridged by image credit New Scientist)

Superposition, on practice

Henri Poincare’, the same scientist who also seeded the ideas later developed by Minkowski, started in his thesis a new chapter devoted to bifurcations. *Bifurcations* are considered in a wide range of physical phenomena, the most known being the Dynamical Systems.

Bifurcation Theory studies the bifurcation hyper surface in the space of vector fields. Some common examples of vectors: wind speed, particles’ collisions or photons' 4-vectors when dealing with the electromagnetic phenomena.

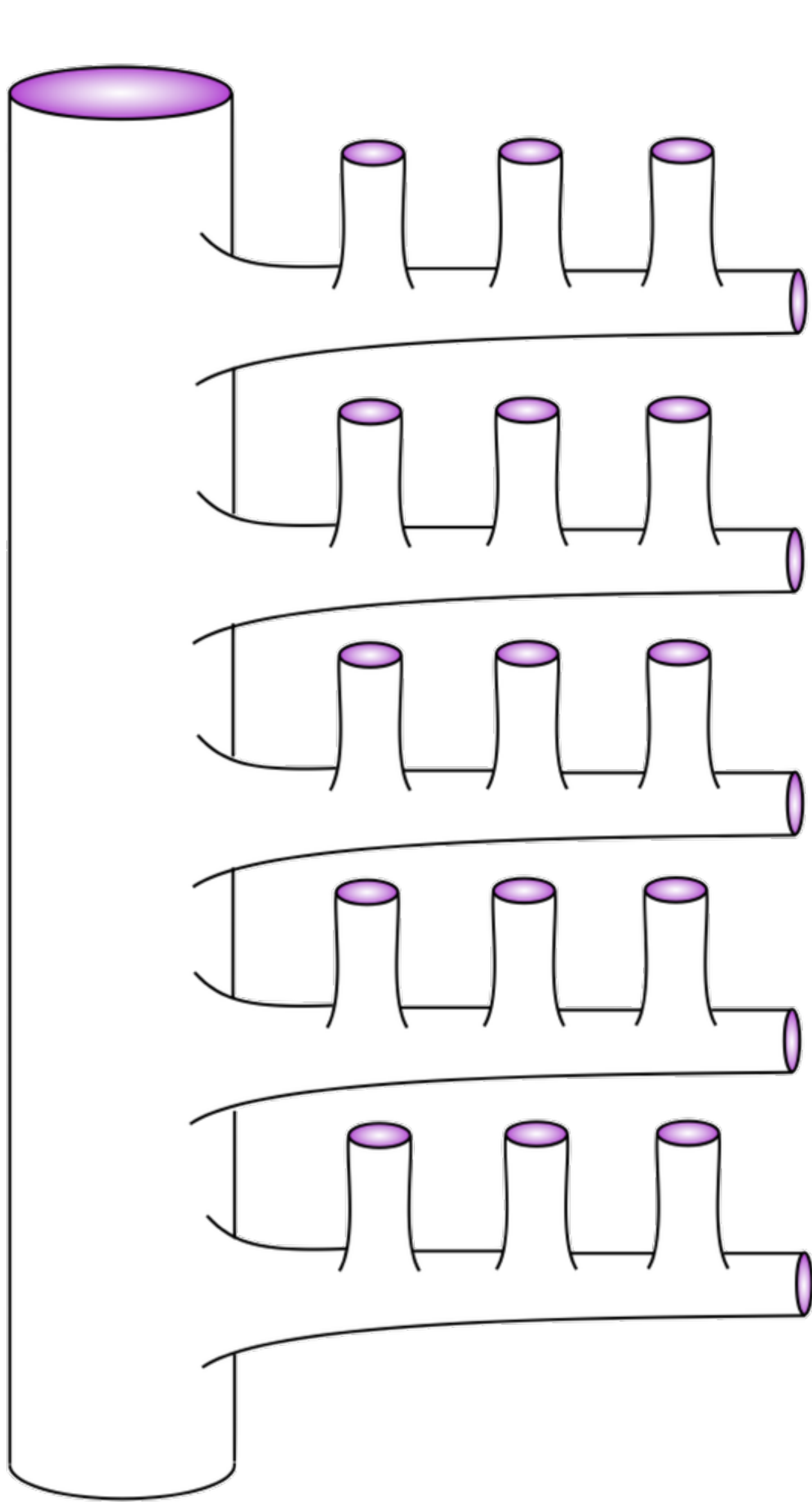
They are bifurcations the:

- Feynman's *paths*, he integrated in 1948;
- Everett's *states*, he described in 1957, constantly branching, transforming from state to superposition with each successive measurement.

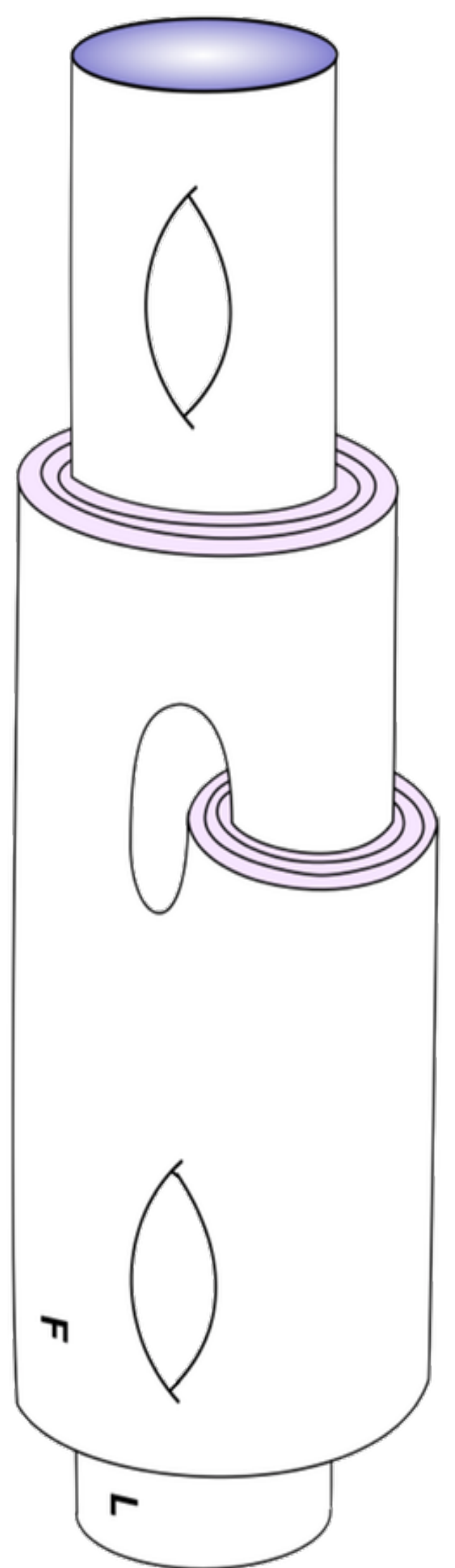
As we saw above, looking for a way to integrate in a unified theory all of the known forces and particles yet discovered, String Theorists passed to a description of Membranes (M-theory): elastic membranes. Bidimensional membranes, in the mainstream version of the theory actually accounting for total 11 space-time dimensions. This position, an effect of the introduction of a new branch of Geometry (Calabi-Yau manifolds) in Physics, has the force to appear fully justified also to non-specialists. When simply looking at the figures below, we discover that the manifold on right side is the same of that on left side, after having been wrapped up as a leaf inside a foliation. And, it is not something *possible*, because its existence is assured by a Theorem.

Visibly, the manifold below on left side describes a tree-like structure of multiple bifurcations.

A multiplicity first detected by Schroedinger in what the equation **[5]** implies: that multiplicity Everett related in 1957 to a tree-like structure, well before Calabi’s geometrical conjecture and Yau’s demonstration. Net sum of what above: a convergence of disciplines toward a single new paradigm, one which is going to open a wealth of technological opportunities.



▲
One
and the
same



manifold, however looking two different ways.
The one right side has been obtained has been
obtained by the one on left side, after having
been wrapped up as a leaf inside a foliation.

Easy to discern that foliations and branchings are one and the same structure

Ranges of grey

And, if you followed us until this point of the bleeding sphere of Physics, no doubt you are perceiving the strident contrast between what we are used to consider *reality* and what **Reality** really is. How we formed that idea of reality ?

Part by genetic inheritance and the majority by the billions of billions of *frames*. Frames recorded in our own memory as *engrams*, originated by the encoding in chemical form of the incoming electromagnetic form of the energy. A multitude of “good measurements”, following Hugh Everett III original definition abridged by the modern Quantum Field Theory, allowed this conversion.

The camera on right side is a professional instrument, one of the best existing today with its 4K capability, something which shall be a standard in 10 years. The camera is based on a massive 3840 x 2160 pixels sensor. Videos' maximum frame rate is 30 fps. Ultra HD 4K is four times the size of 1080HD, with twice the vertical and twice the horizontal resolution. The video below, shot in black and white following the laymen point of view and in ranges of grey for a Machine Vision professional, has a size reduced to 3840 x 1600 pixels. 1 minute and 42 seconds only of *informations* resulted in a file size of over half a gigabyte. The best way to really see the amount of informations present in the video implies a 4K display and full screen. If streaming it by Internet, it'd be necessary a fibre optic connection.

A video showing, in the words of Sky News®: *"The city of London, shrouded in a Dickensian blanket of smog, as light winds, Sahara dust, and dirty air from the continent conspire to produce air pollution levels right at the top of the chart"* is here available for download (<https://vimeo.com/92404406>). We choose this particular video to homage the United Kingdom. The Multiversal Revolution, started in 1957 by a young student at the Institute of Advanced Studies of the quiet Princeton, New Jersey, USA, is since decades carried on toward further impressive successes in the United Kingdom. At Oxford, Cambridge, Leeds, London, Birmingham, Edinburgh to name only a few of the many towns hosting the Universities and Laboratories where the research happens between the fogs visible in the video.

Looking the footage shot by mean of one of the best existing cameras, maybe you'll perceive ***how far from the Reality*** is the idea of reality in the minds of the peasants populating the video. This video introduces you to the following section devoted to the first practical uses of the multiversal revolution, devoted to the computation made directly in portions of the Hilbert Space existing on the Earth, in our Laboratories and Factories.



▲ At a massive 3840 x 2160 pixels, Ultra HD 4K is 4 times the size of 1080HD, with twice the vertical and twice the horizontal resolution. But, also this Australian-made professional camera, one of the World's best, is not capable to record informations corresponding to what Reality is made of (image abridged by picture credit Blackmagic Design Pty. Ltd., 2014)

▲ The Multiversal Revolution started by a student in 1957 in the Institute of Advanced Studies of the quiet Princeton, New Jersey, USA, is since decades carried on toward further successes in the United Kingdom. At Oxford, Cambridge, Leeds, London, Birmingham, Edinburgh to name only a few of the many towns hosting the Universities and Laboratories where the research happens between these fogs (video credit B. Bell, 2014)

Computing in the Hilbert Space

The following video, originating by the world leader in quantum computing, D-Wave Systems, Inc., is meant as an introduction to commercial applications of the superposed structure named Multiverse. **One of the applications of the quantum computers is the Binary Classification. Electronic Inspectors in the Food and Beverage Bottling Lines are Binary Classifiers.** (In another page of this site we'll explain why the ideal Bottling Control is a device calculating in binary way as usual but, in the Hilbert space). From Decoherence we learnt that the general mechanisms and phenomenons arising from the interaction of a macroscopic quantum system with its Environment, strictly depend on the strength of the coupling between the considered degree of freedom and the rest of the world. And, because of this reason D-Wave's "Vesuvius" Central Processing Units are a system of 512 quantum bit (short: qbit).

512 superpositions of the Ψ wave functions, preserved longer than possible in the Hilbert space:

- operating at temperatures of 0.02 K (-272.98 °C), extremely close to the absolute zero;
- protected by induction of external electromagnetic fields by fifteen levels of Faraday cages.

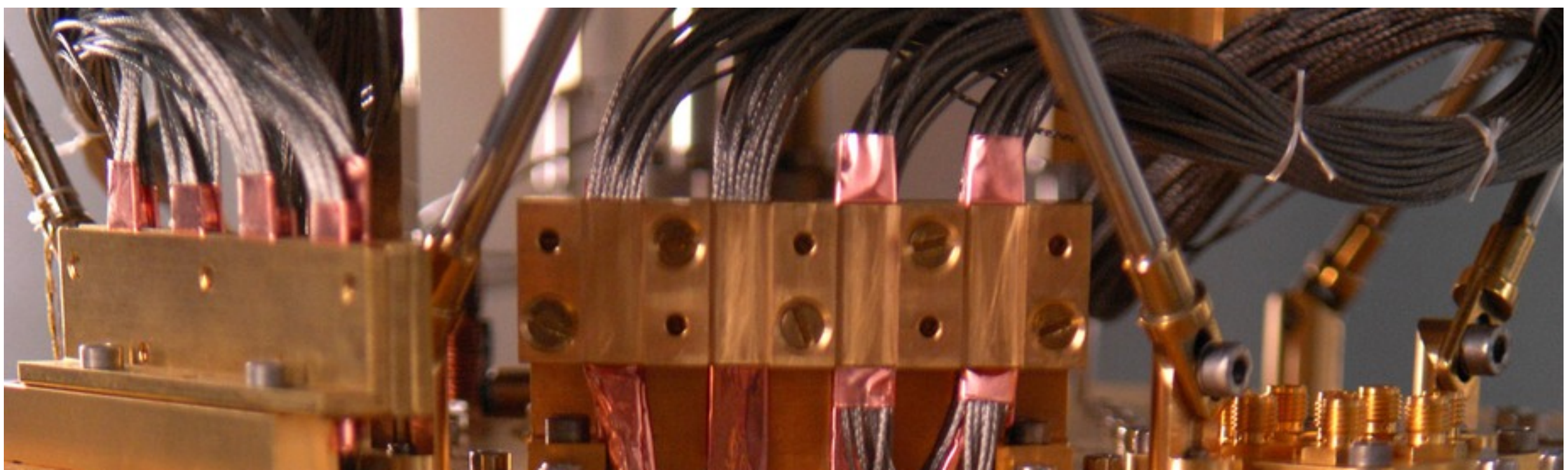
A mind-boggling amount of other branches of the Multiverse where the computer exists, each one processing the same original qbit with differences from one to another in the variable processed, reduced to 1 bit.

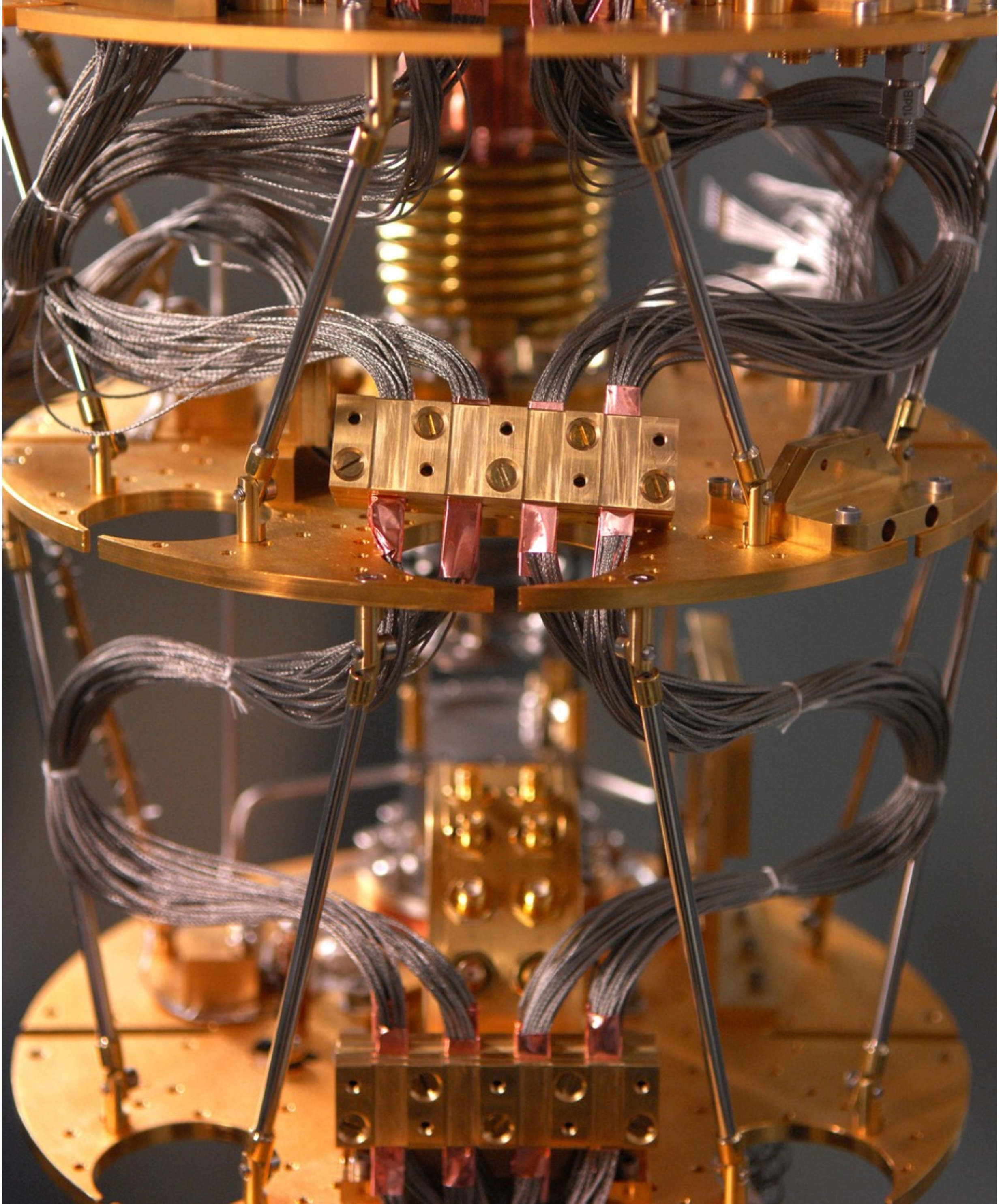
Moreover they:

- adopt Rainier processors and Josephson-effect junctions, rather than Silicium-based processors. Josephson junctions are the most basic mesoscopic superconducting quantum device;
- handle qubits which can slowly be tuned (annealed) from their superposition state (say where they are 0 and 1 at the same time) into a classical state where they are either 0 or 1. When this is done in the presence of the programmed memory elements on the processor, the 0 and 1 states that the qubits end up settling into gives the answer to an user-defined problem.

"One of the applications of the quantum computers is the Binary Classification.

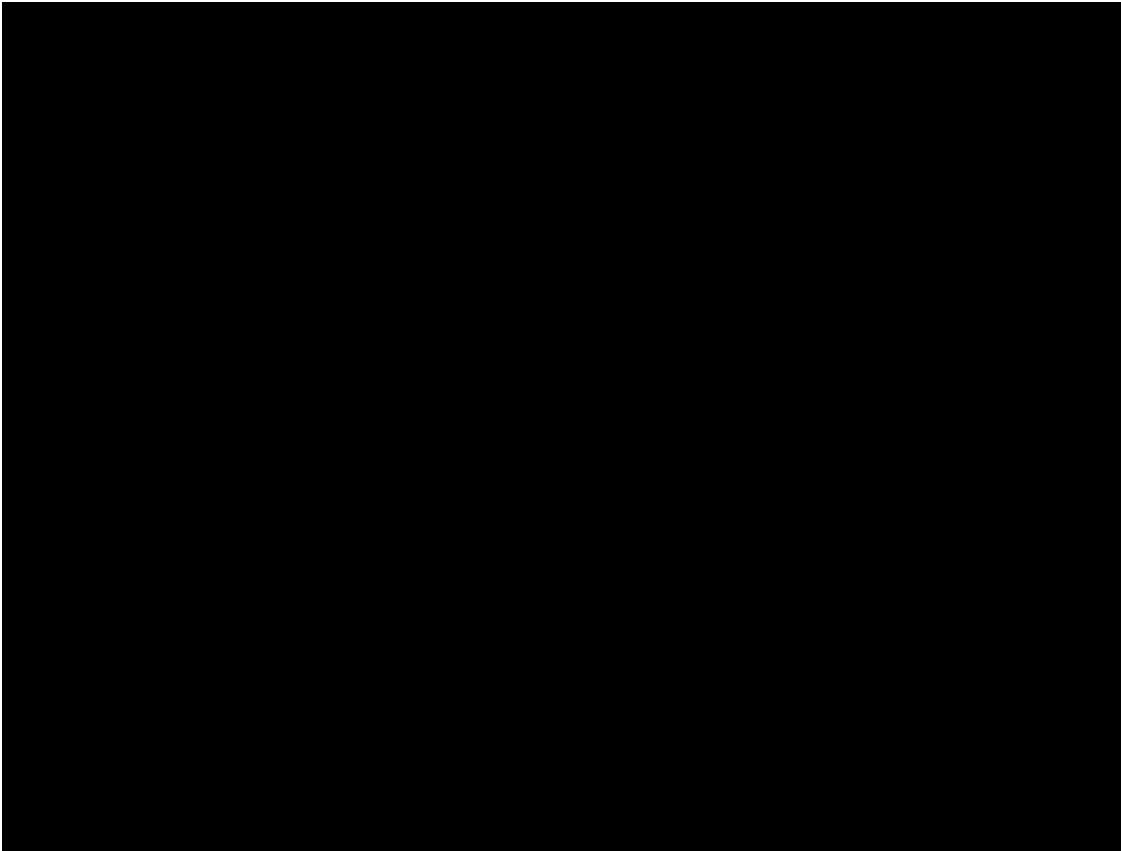
All Electronic Inspectors, whatever their size, complexity or task, are Binary Classifiers"





▲ To create small and short duration Hilbert spaces here on the Earth surface requires a technology completely different than actual Supercomputers, technology which is the core of the new Quantum Computers. Nearly *Science Fiction*, as seen by the point of view of today Industrial Automation. One of the key points lies in the fact that superpositions of the Ψ wave functions are preserved longer than possible in the Hilbert space when: 1) operating at temperatures of 0.02 K (-272.98 °C), extremely close to the absolute zero; 2) protected by induction of external electromagnetic fields by the shielding provided by fifteen levels of Faraday's cages. This image is showing extreme cares with respect to both points: 1) the entire circuit lies in a fridge. 2) EMI-induced parasitic currents flowing in the shields of the cables carrying Signals, are immediately discharged to Ground. This, limiting to < 250 mm their extension far

from Ground discharge points massive and whose impedance is extremely low. In other terms, also EMI-induced parasitic currents are conceived in the framework of the wider circuital design (image courtesy of D-Wave Systems Inc., 2014)





Inspections in a Decohering Environment

“Around the Electronic Inspectors the decisive factor and most often overlooked: the Environment”

What is a measurement ?

Measurement’s nature is one those things we know, until we are not compelled to explain to someone else. Explanation invariably passing thru the idea of comparison between a standard established before and something else. In the reality, this answer we all know, the one taught us in the Electronics, Electrotechnics and Engineering courses at whatever level, is today considered a Classic one. A soft way to say *obsolete*. Slowly, the idea of measurement has changed from the initial mere comparison rule, to something completely different. It has been reshaped, following what understood by the discoveries of the past century. In the Classic perspective, a physical measurement requires a collection of devices such as a clock, an encoder, a phototransistor, a theodolite, a counter, a LASER LED, a temperature or pressure sensor, and so on.

The operational control of this instrumentation is exercised alternatively by the **Observer**, who decides what to measure, how to perform a measurement, and how to interpret the results.

Inspections in a Decohering Environment



(inspections-are-measurement.pdf)

(inspections-are-measurement.pdf)

(inspections-are-measurement.pdf)

23 pages, 4 MB

“As models for Observers we can, if we wish, consider **automatically functioning machines**, possessing sensory apparata and coupled to recording devices capable of registering past sensory data and machine configurations. We can further suppose that the machine is so constructed that its present actions shall be determined not only by its present sensory data, but by the contents of its memory as well. Such a machine will then be capable of performing a sequence of observations (measurements), and furthermore of deciding upon its future experiments on the basis of past results”.

Visibly, this second choice fulfill strictly all of the features of an *inspection* in an Electronic Inspector, or of one of the assembles composing an Automatic Machine, like the Conveyors, Filler, Closer, Blowformer, Palletiser, etc.

Established these basics, we all agree a physical measurement is meaningful only if one identifies in a non ambiguous way:

- who is the observer (or, apparatus, or automatically functioning machine);
- what is being observed.

The same observable can be the target of more than one observer (or, automatically functioning machine) and that’s why we need a suitable algorithm. Because of this reason it is also needed a suitable algorithm to compare their measurements.

In the following, we’ll just briefly introduce two points of view about the nature of physical measurements:

- classic, a relativistic point of view based over Differential Geometry;
- modern, the Quantum Physics point of view based over Quantum Field Theory

Being two distinct point of view about the same subject, many terms shall be purportedly repeated. This introduction *tries* to abide by the necessary formalism, here replaced by figures and graphics. The goal of this introduction along twop different pathways, is to show how similar conclusions about what a measurement really is, get out naturally by theories substantially different and developed in different epochs.

Local and non-local measurements

The Electronic Inspector and the ambient containing it, cover a finite spatial volume making measurements lasting for a finite interval of time. The measurement’s domain is the space-time region in which a process of measurement takes place. In a following section we’ll deepen this point, showing how wide results the domain of the automated quality control equipments, volume commonly imagined reduced to the Bottling Hall. If the background curvature can be neglected, then the measurements will not suffer from curvature effects and will then be termed *local*.

On the opposite, if the curvature is strong enough that it cannot be neglected over the measurement’s domain, the response of the instruments will depend on the position therein and therefore they require a careful calibration to correct for curvature perturbations. In this case the measurements carrying a signature of the curvature will be termed *non-local*.

Apparatus and physical measurements



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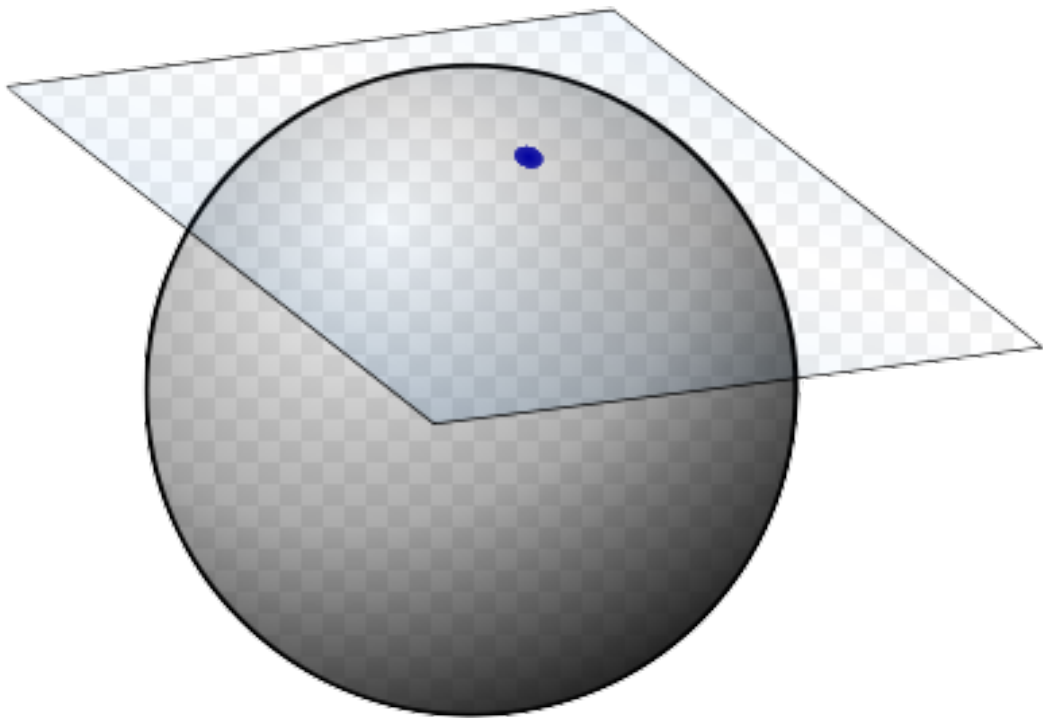
“As models for Observers we can consider automatically functioning machines, possessing sensory apparata and coupled to recording devices capable of registering past sensory data and machine configurations. We can further suppose that the machine is so constructed that its present actions shall be determined not only by its present sensory data, but by the contents of its memory as well. Such a machine will then be capable of performing a sequence of observations (measurements), and furthermore of deciding upon its future experiments on the basis of past results”

“A physical measurement is meaningful only if one identifies in a non ambiguous way who is

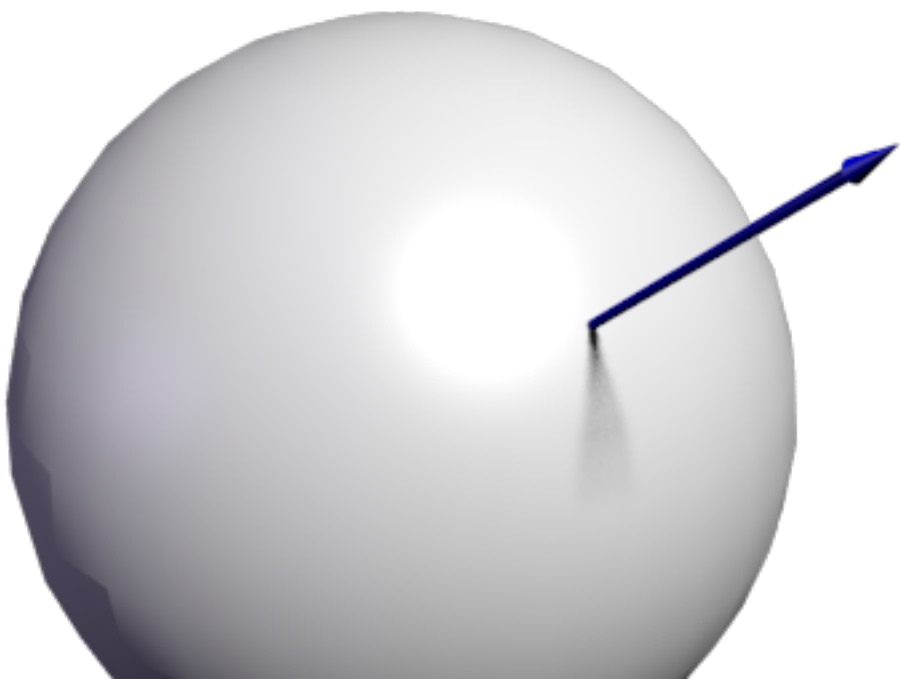
In mathematics, the tangent space of a manifold simplifies the generalization of vectors from the affine spaces to the general manifolds. An example of tangent space is given in the figure on right side. A generalization made necessary because in the latter case, what we all learnt by elementary vector algebra, when subtracting two points to obtain a vector pointing from one to the other, is not possible.

the observer (or, automatically functioning machine) and what is being observed”

Whatever, and also an **automatically functioning machine** (e.g., an Electronic Inspector) and the environment containing it, is mathematically modeled by a family of non-intersecting time-like curves having \mathbf{u} as tangent vector field and denoted by \mathbf{Cu} .



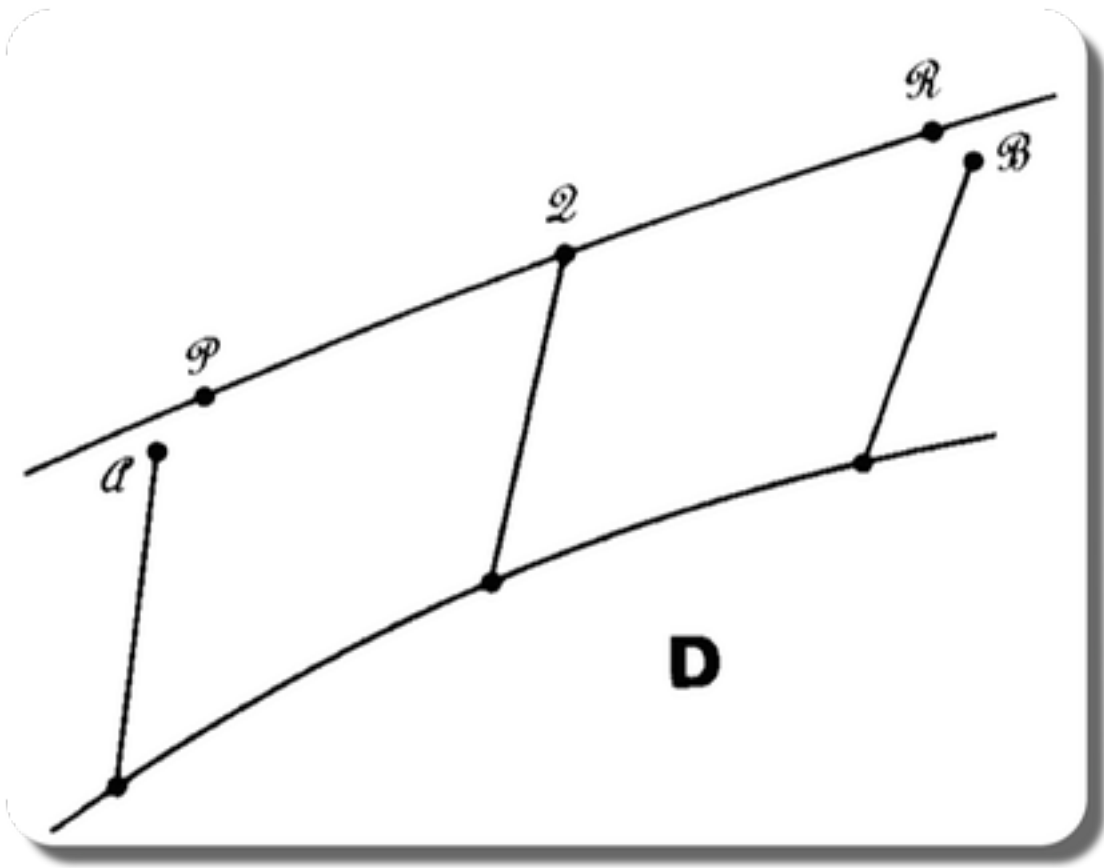
▲ A tangent space of a single point on a sphere. Generalising the concept, to every point of a differentiable manifold, can be attached a tangent space. Tangent space is a vector space containing all possible directions along which one can pass through the point (image credit csdn.net, 2014)



▲ A vector normal to the surface

Here, \mathbf{Cu} is the congruence of curves with the

tangent field. Each curve of the congruence represents the history of a point in the laboratory or automatically functioning machine. We choose the parameter t on the curves of \mathbf{Cu} so as to make the tangent vector field \mathbf{u} unitary, an always possible choice for non-null curves. Let Σ be a space-like three-dimensional section of \mathbf{Cu} spanned by the curves which cross a selected curve γ_s of the congruence orthogonally. The concepts of unitarity and orthogonality are relative to the assumed background metric. The curve γ_s will be termed the fiducial curve of the congruence and referred to as the world line of the observer, apparatus or automatically functioning machine.



▲ A vector normal to the surface and a family of the infinite class of the associated tangent vectors

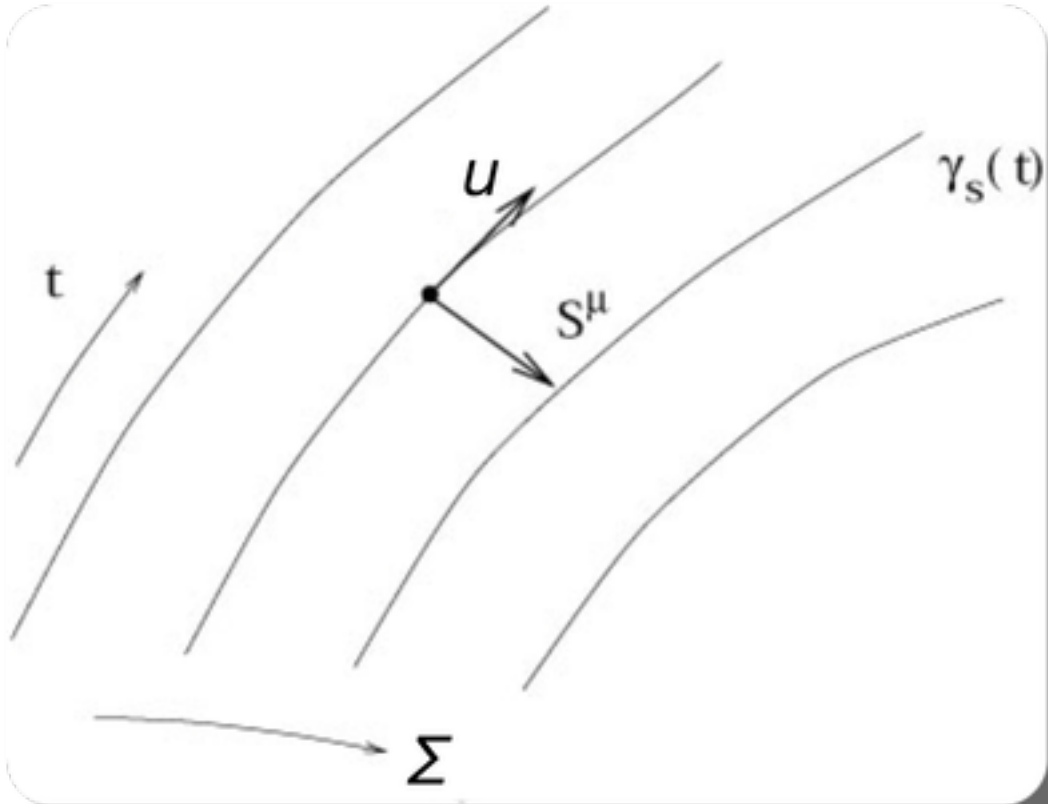


represents the space-time history of the observer's laboratory or the electronic inspector and its environment. Limiting the extension of Σ to a range much smaller than the average radius of its induced curvature, it becomes possible to identify:

- C_u with the curve γ_s
- Σ with the point $\gamma_s(t)$

Any time-like curve γ with tangent vector u can then be identified as the world line of an observer (or, electronic inspector) which will be referred to as “the observer u ”. If the parameter t on γ is such as to make the tangent vector unitary, then its physical meaning is that of the proper time of the observer u . As an example, the time read on his clock in units of the speed of light in vacuum.

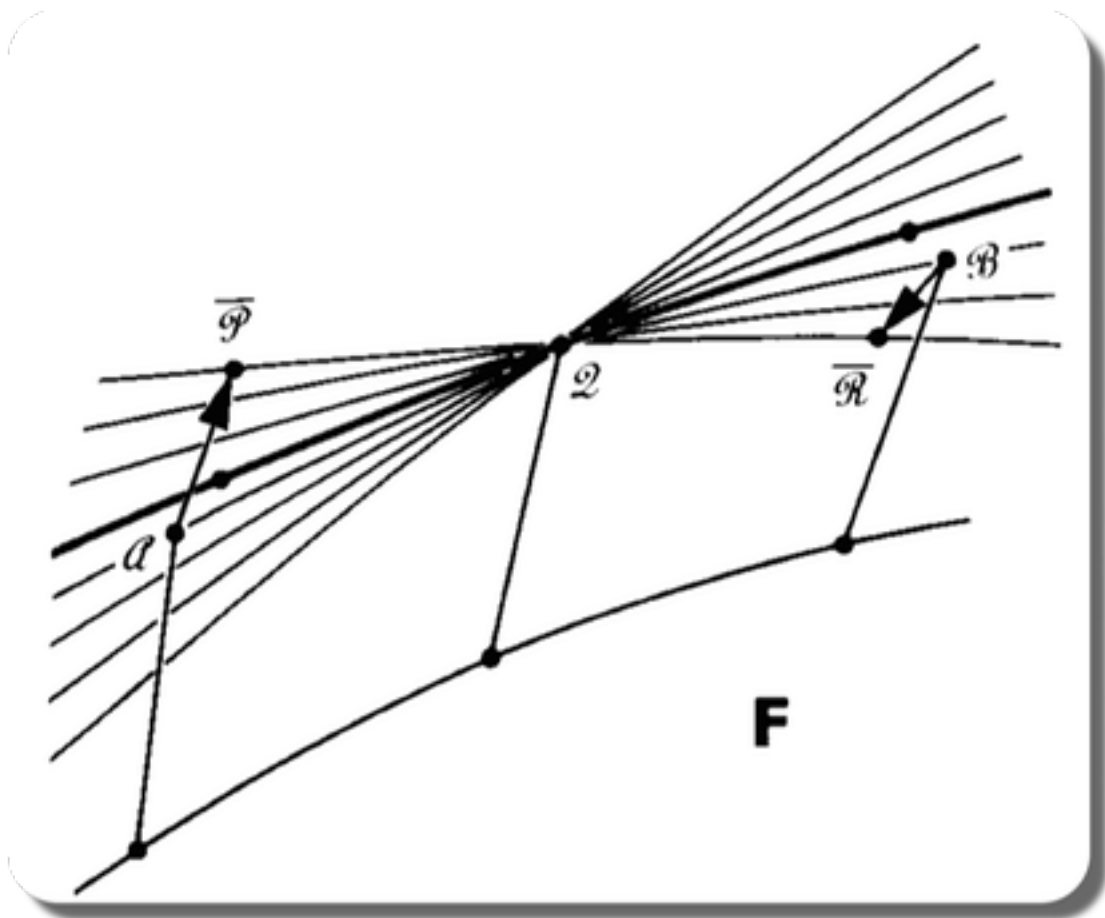
Let the point of intersection of Σ with γ_s be:
 $\gamma_s(t)$
 As a consequence, during the continuous variation of t over γ_s we'll observe the section Σ spanning a 4-dimensional volume. This volume



▲ **Four non-intersecting time-like curves having u as tangent vector field. All automatically functioning machines are mathematically modeled by a family of such curves, denoted C_u**

Reference frames

This concept of observer, apparatus or automatically functioning machine however, needs to be specialized further, defining a reference frame adapted to him. A reference frame is defined by a clock which marks the time as a parameter on γ , as already noted, and by a spatial frame made of three space-like directions identified at each point on γ by space-like curves stemming orthogonally from it. While the time direction is uniquely fixed by the vector field u , the spatial



directions are defined up to spatial rotations, i.e. transformations which do not change u . Obviously there are infinitely many such spatial perspectives, whose effect is evidenced by the figure on left side. Here, alternative courses that a test geodesic could have taken through (*could have taken through*, has been replaced after 1990 by the modern *took through*). The result of a physical measurement is mathematically described by a scalar, a quantity which is invariant under general coordinate transformations. A scalar quantity, however, is not necessarily a physical measurement. The latter, in fact, needs to be defined with respect to an observer and in particular to one of the infinitely many spatial frames adapted to him. The aim of the relativistic theory of measurement is to enable one to devise, out of the tensorial

▲ **A family of alternative courses that a test geodesic *could have taken*, all of them through the point Q . The *could have taken through*, has been replaced after 1990 by the**

modern *took* through. The word alternative has been replace by *actual*. The family of geodesics shown features different degrees of convergence toward the right side, or divergence toward left side (image credit J. A. Wheeler, *et al.*, 1973)

representation of a physical system and with respect to a given frame, those scalars which describe specific properties of the system.

The elementary measurement

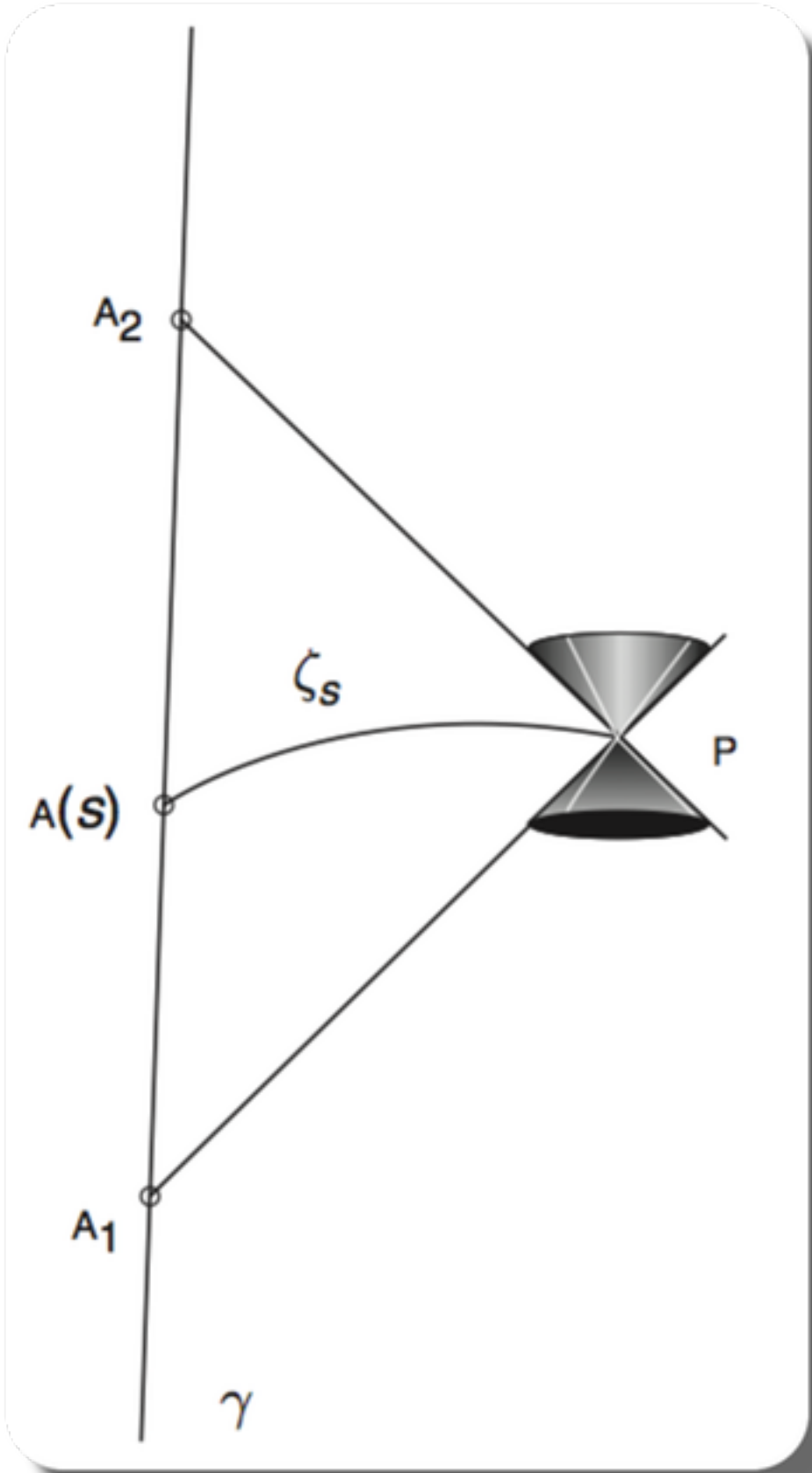
It can be a pressure sensor in a squeezer™ Leakage Electronic Inspector, or a capacitive sensor in a Weigh Checker for cases or clusters of bottles or cans, it can be a High Frequency fill level inspection, X-rays or the most daily sight we give to the world when we awaking, these all are electromagnetic measurements.

The only non-electromagnetic measurements whose effects we can feel, are those happening at other levels, namely:

- nuclear, like those originating the (abandoned) gamma-rays fill level inspections;
- gravitational.

To let an electromagnetic interaction be considered a good measurement, it is necessary:

1. **Time**, to transform the previous state, in which all possible kinds of correlation between observer (or, his models, like all automatically functioning machines) and the object of the measurement coexist, in a following state in which the observer is “aware” to be correlated to an object, because having recorded eigenvalues for the eigenfunction Φ_{iS1} describing the object. The correlation between the two systems is progressively established during interaction and proportional to the natural logarithm ($\ln t$) of the interaction time t . An ideal correlation, corresponding to a maximised information of the observer (or, his models, like all automatically functioning machines) about the object, can only be reached allowing an infinite time. The fact we cannot wait for an infinite time causes the measurements’ fluctuations, a synonymous of the spectrum of the eigenvalues, resulting in the Electronic Inspector's false positives (false rejects). Time, for what ? To transform the previous state, in which all possible kinds of correlation (superpositions) of the observer coexist, in a following state in which the observer is aware to be correlated to an object, because having recorded eigenvalues for the eigenfunction Φ_{iS1} describing that object.
2. **Interaction between the systems such that the information in the marginal distribution of the object inspected is never decreased.** Otherwise we could not have any more repeatability of the measurements. As an example, the instrument used to establish the correlation, for an instance an electromagnetic wave in a common photo-electric sensor, should never modify the molecular structure of the object. Otherwise, it’d be modifying its eigenstates and then the eigenvalues we expected to derive by the measurement.



▲ The relativistic today classic point of view about the most elementary measurement. Imagine a source of light moving along the geodetic γ . It emits a photon at the point A1, reflected back by a mirror existing at the point P, reabsorbed by the observer source of light at

A visible example of such elementary measurement, always present in the industrial machinery, in the automatically functioning machines, in the Electronic Inspectors, in the inspections of which the Inspections are a superposition until the Observers, is visible on right side. Visible following the relativistic and today classic point of view. Imagine a source of light moving along the geodetic γ . It emits a photon at the point A1, instantaneously reflected back by a mirror existing at the point P. Reabsorbed by the observer source of light when this reaches the point A2. Such configuration allow to establish the spatial distance ζ_s between observer and mirror, along the curve separating them.

the point A2. Such configuration allow to establish the spatial distance ζ_s along the curve separating the observer (or, his operative models, like the inspections by the mirror (image credit De Felice, Bini, 2010)

Modern interpretation of physical measurements

Who measures what, from where and when ?

The basic measurement mechanism described immediately before, corresponds to a classic point of view. Since decades replaced by a completely different one. The measurements are in general observer-, inspection- or automatically functioning machine-dependent. Because of this reason, a criterion should also be given for comparing measurements made by different observers, inspections or automatically functioning machines. The relevance of the comparison between different observers, inspections or automatically functioning machines was discovered nearly one century ago. More than fifty years ago it started to become clear why this dependance. A basic role in this procedure of *comparison* implicit in the measurement, is played by the Lorentz group of transformations. A measurement which is observer-independent is termed Lorentz-invariant and Lorentz-invariant measurements are of key importance in physics. Why ? Because the description of a physical system depends both on the observer, inspection or automatically functioning machine and on the chosen frame of reference.

In most cases, the result of a measurement is affected by contributions from the:

- background curvature;
- peculiarity of the reference frame.

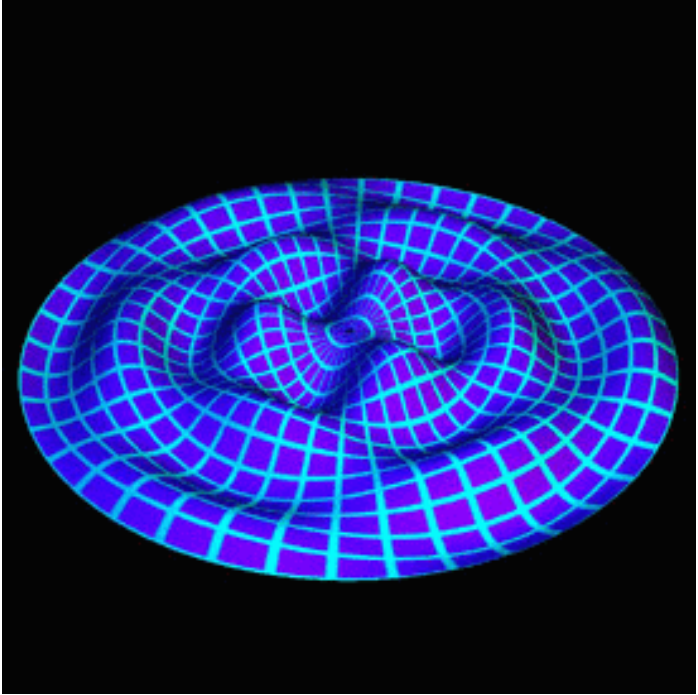
Riding geodetics

As long as it is not possible to discriminate among them, a measurement remains plagued by an intrinsic ambiguity. This ambiguity, whose existence was clear yet sixty years ago to Albert Einstein who General Relativity created, is not an accidental. It hints to the multiple actual courses that a test geodetic can take through. And we, our inspections and automatically functioning machines ride these geodetic. The *statistical nature of measurement*, hinted by the video in the start of this web page, is an illusion. No measurement, by an observer, inspection or automatically functioning machine is *statistical*. Rather, it is strictly deterministic and linear. *The measurements' results, e.g. the gaussian expected distribution of the independent measurements of a random variable, are not random at all.* It is directly the statistical interpretation of measurements to be flawed by obsolescence. In the modern, experimental and theoretical perspective, each one measurement corresponds to one of the existing (existing or actual, and not *possible*) eigenvalues of the eigenvector including the observer and of its generalisations (the inspections or the automatically functioning machines). An eigenvector whose complete set of values *exists* only from the point of view of a superior superposition, the sum of all the superpositions. An *existence* in the sense that only the superior superposition has all of the knowledge for all of the eigenvalues of all of its eigenvectors. We all observers

and all our operative generalisations, like the inspections or the automatically functioning machines, have energy and extension limits. Because of this excellent reason, quite obviously we can only have an extremely limited perception and memory of the multitude of the coexisting eigenvalues.

To clear the comprehension of this truly fundamental concept, please refer to the figure on right side. There, each point of the surface of the drum head is indexed by a couple of (x, y, z) coordinates where x, y are the common cartesian bidimensional coordinates, and z the height (or, depth) of the point. *Each one of the infinite points of the surface of the drum head exists before and after the measurement, also if associated to different values of the height z.* There is a multitude (not infinite) of values of the z coordinate which may be associated with each one point x, y.

Returning to the differential geometry classic point of view described by the figures above, the sum of all of those courses took by a test geodetic. We are speaking of an *actual* multiplicity, obviously fronting the immediate objection: *why we only see a single measurement result ?*



▲ **Oscillation**
***characteristic* values (*eigenvalues*) are modes of vibration. A visible example the upper surface of a drumhead, each one mode oscillating its own frequency (image credit J. Kreso, 1998-2010)**

The following animation below, based over an insight of 1970, allows to start to answer the question. It shows the fine-details of how a measurement happens. Specifically shown what happens to a macroscopic System (a cat), initially in a superposition of states, under the effect of the same Environment in standard conditions of temperature, pressure and humidity where also all Food and Beverage Controls operate. It is, visibly, a smooth continous process. Displayed the reconstructed Wigner function of the System averaged over 4 ms, reconstructed with the data recorded in a 4 ms sliding time-window (credit CNRS, Laboratoire Kastler Brossel).

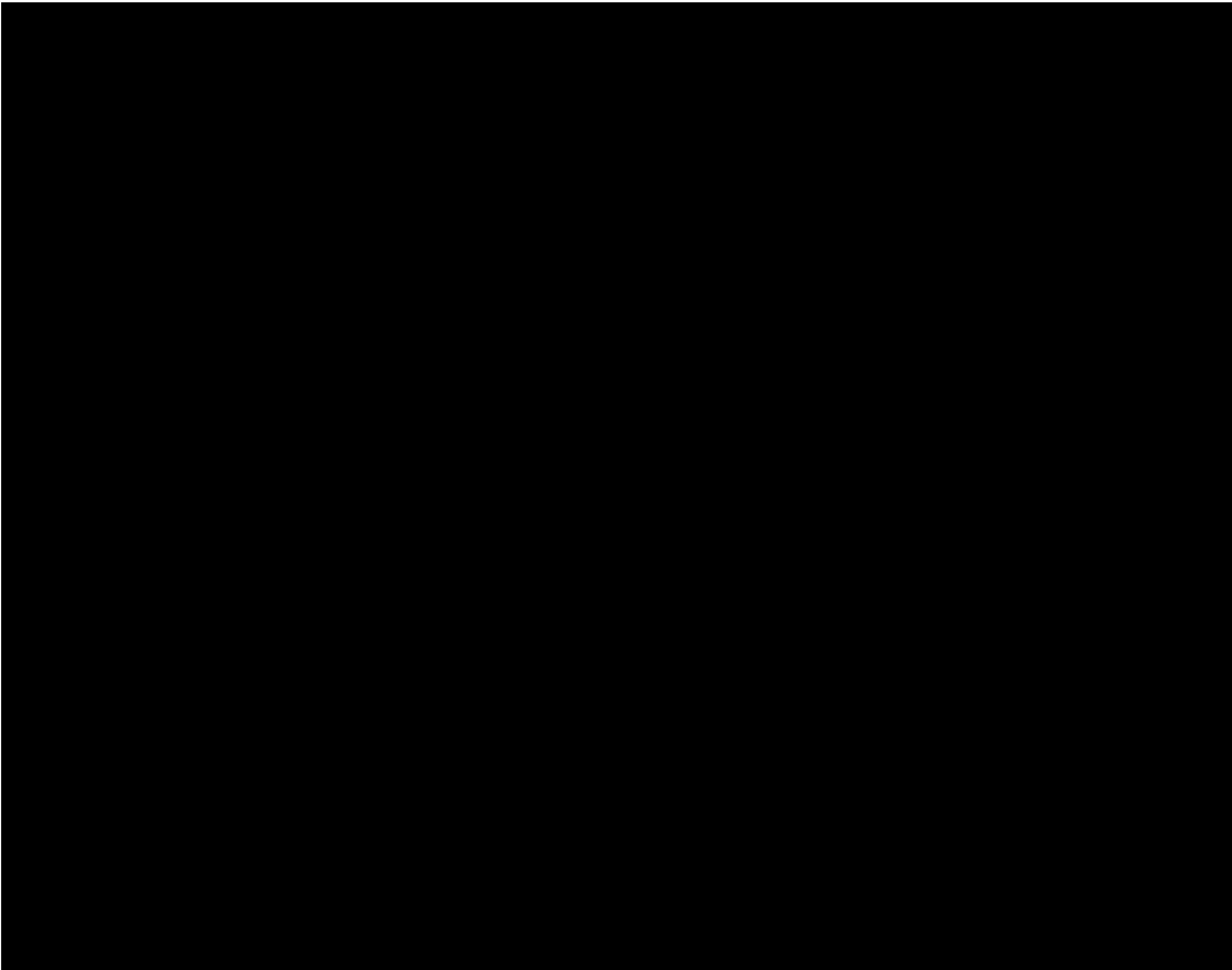
Two different phenomena are visible:

- a fast decay of the quantum interference feature, in the few initial milliseconds;
- a much slower evolution of the classical components towards phase-space origin.

In the following, it’ll become clear how deeply and constantly these modern subjects intervene in the function of the Electronic Inspectors and their measurements (inspections).

Along past three decades Decoherence explained why:

- certain microscopic objects, commonly named “ articles", seem to be localized in space: in the reality, particles do not exist and only there are waves (see figure on right side);
- microscopic systems are usually found in their energy eigenstates and therefore seem to jump between them, meaning that there are no quantum jumps;
- they appeared to exist two contradictory levels of description in physics (classical and quantum) when there is a single framework for all physical theories: the quantum theory;
- the Schrödinger equation of General Relativity (also named Wheeler-DeWitt equation) born in 1967 may describe the appearance of Time in spite of being Time-less. It has been understood that Time does not exist and what it really exists is an arrow of time in the form of a special initial condition.



Electronic Inspection and Quantum Physics:

a common ground

Inspections can be thought as *finalised measurements* or, *measurements with a scope*. Where the scope is the rejection of the object. Whatever object (bottles, cans, crates, cases, kegs but also wheels, smartphones, blood samples, glue, pens, gaseous substances, etc.) where at least one measured physical quantity, resulted out of a pre-defined range. Physical measurements are the core of Bottling Controls Technology and operation. Around the Electronic Inspector there is the decisive factor, and most often overlooked: the Environment. Electronic Inspectors (or, Bottling Controls) in Food and Beverage production Lines are collections of assemblies, named *inspections*, whose components are Optoelectronic devices performing physical measurements of the properties of objects (containers, crates, cases, etc.) and their content, mainly by mean of electromagnetic measurements. In this framework, Triggers are the most basic devices, those controlling the successive actions of physical measurement and eventual rejection in a Binary Classifier. A physical measurement requires a collection of devices in our case clock systems integrated in the Inspector's electronics, Encoders, counters, LASER photosensors, CMOS-cameras, High Frequency residual liquid controls, and so on.

The operational control of this instrumentation is exercised in the phase of the Inspector startup and commissioning by the field Engineer, who calibrates amounts corresponding to Contractual Agreements about:

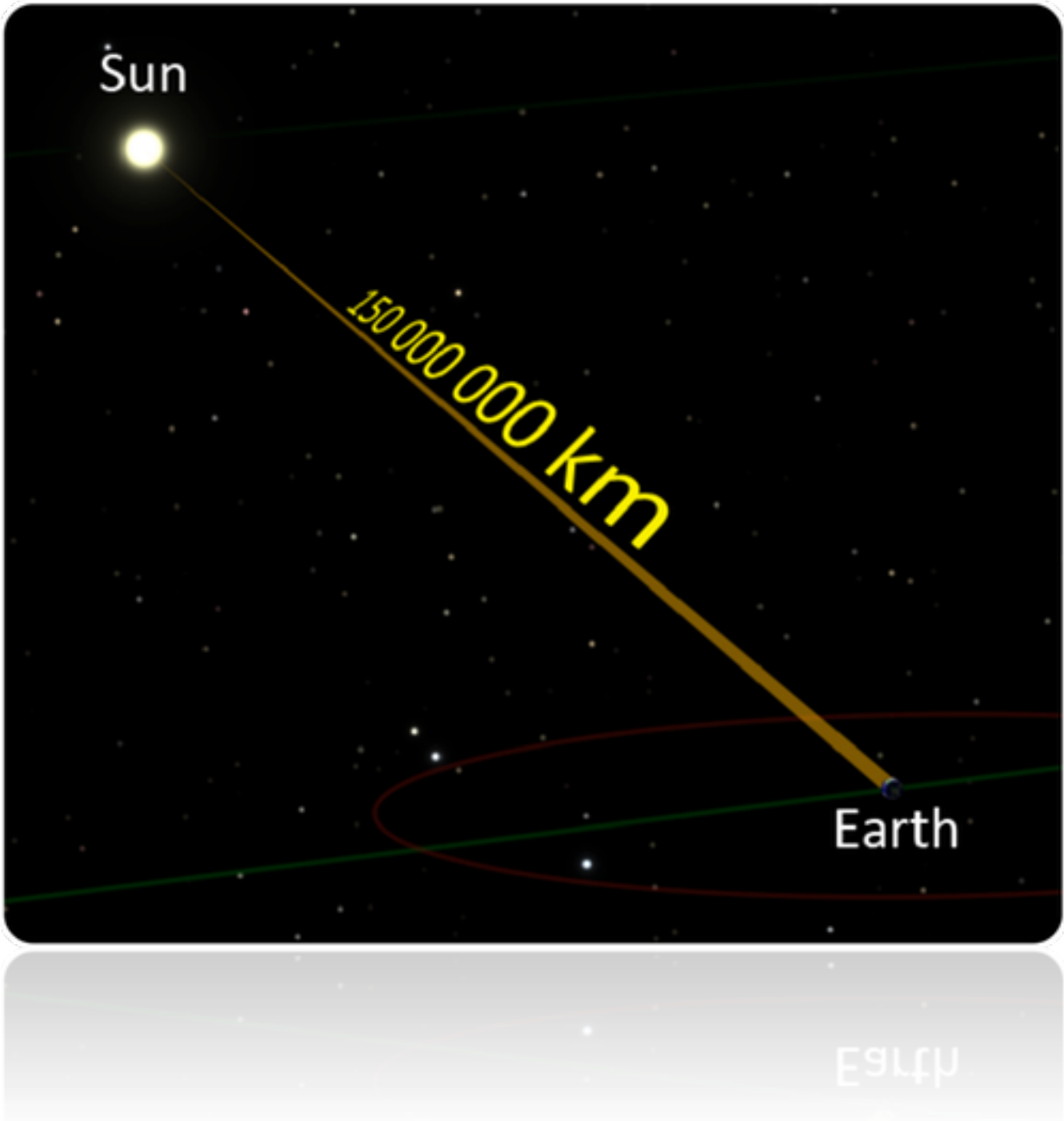
- what to measure,
- how, where and when to perform a measurement,
- how to interpret the results.

Environment, the measurements' *domain*

The Food and Beverage Bottling Line covers a finite spatial volume and the measurements last for a finite interval of time, in our case commonly ranging: (0.1 - 20) ms. In general, it is defined as the measurement's "domain" the space-time region in which a process of measurement takes place. The Sun (see figures on right side) is capable to repeatedly stop along tens of minutes an entire Beverage Bottling Line. How ? In its most natural way, by mean of beams of light which are one of the two known causative relations (the second being gravitons) between the measurements accomplished in our Factories here and now, and that object 149.5 millions of kilometer afar and ~8.5 minutes ago.

We'll cite four different examples, all of them referred to our specific field of application, automatised Quality Controls in the Food and Beverage Bottling Lines:

1. photons in the visible part of the spectrum, due to reflections into Inspectors' mirrors are later amplified, forcing massive false rejects (> 40 %) in Full Bottle and Empty Bottle Inspectors equipped with Vision cameras;
2. photons in the visible part of the spectrum, in feeding cap Colour tri-chromatic sensors



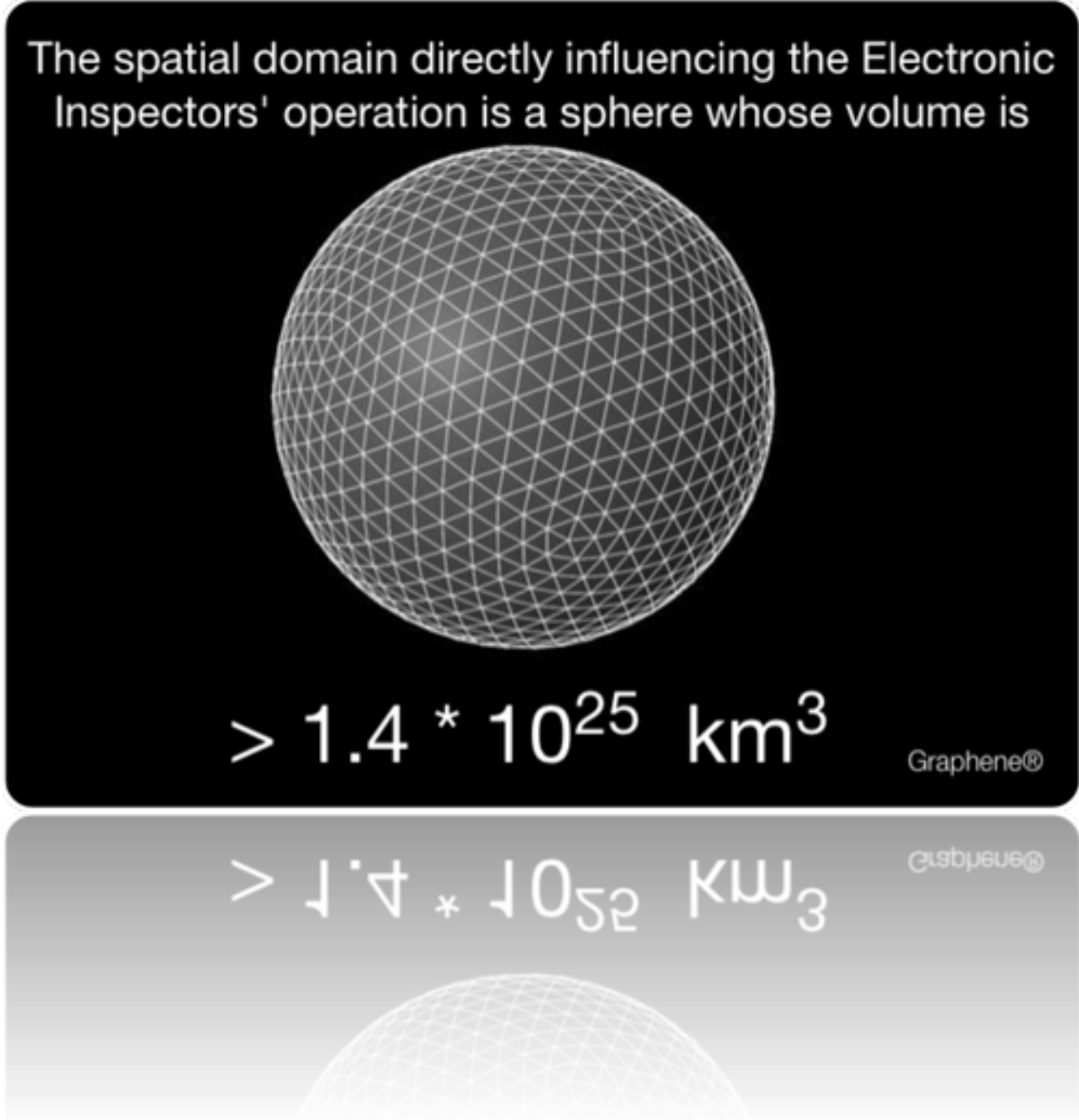
▲ The Environment causally connected with our Bottling Controls is wider than the Factory in which they operate. An entire Food and Beverage Bottling Line can be stopped by the false rejects whose unique, 8.5 minutes delayed cause, lies 150 millions of kilometres afar: the Sun. But, also apart the limit case here described, sun beams act constantly in the productive process, creating a daily cycle causing apparent spontaneous sensibilisations of the Bottling Controls' inspections and the opposite effect around twelve hours later

- and later amplified, emulate caps of wrong colour, forcing massive false rejects ($> 10\%$) in Full Bottle Bottle Inspectors equipped with cap Colour inspection;
3. thermal photons act on beverage characteristic creating a diurnal cycle. A beverage whose fill level is being inspected with high frequency em radiation, appear apparently underfilled at ~ 3 PM than at ~ 5 AM. Net effect front of a single sensitivity setup: huge false rejects at ~ 3 PM;
4. thermal photons act on the PET bottles characteristics, creating a diurnal cycle. PET containers tension shall be minimised at ~ 3 PM and maximised at ~ 5 AM. A PET container whose sealing (leakage) is inspected by mean of a Squeezer Full Bottle Inspector, equipped with inspection for pressure, inductive seal and difference of fill level, shall appear defective at ~ 3 PM and correctly sealed at ~ 5 AM.

Classic interpretation

Reading from the classic Physics point of view the last two of the four cases above, we see a common cause (written in italics) for the “measurement anomaly”:

3. the beverage at ~ 3 PM cannot be inspected for HF fill level like at ~ 5 AM, *because the Environmental conditions are different*;
4. the PET container at ~ 3 PM cannot be inspected for sealing like at ~ 5 AM, *because the Environmental conditions are different*;



Modern interpretation

Re-reading from the modern Physics point of view the last two of the four cases above, it is detected (and, tentatively eliminated) an ambiguity in the Classic Physics point of view, causing approximation:

3. the beverage at ~ 3 PM cannot be inspected for HF fill level like at ~ 5 AM, *because the correlation between Environment and beverage is different*;
4. the PET container at ~ 3 PM cannot be inspected for sealing like at ~ 5 AM, *because the correlation between Environment and container (mechanical characteristics) is different*.

▲ The smallest and strictly causally connected Environment is a huge sphere, centered in the Factory, whose volume is $1.4 * 10^{25} \text{ km}^3$

Out of this sphere, there is the much wider heliosphere where the Sun act also, preventing the dangerous arrival on the Earth surface of the majority of atomic nuclei and electrons, flying at relativistic speed and of high energy photons, gamma and X-rays. All these mere byproducts of the multitude of physical Events happening into clouds and into those gigantic fusion energy-based reactors, collectively named *stars*. A small portion of them reach however the surface and our Machinery, implying one more reason for the fact that it is unavoidable to experience measurement fluctuations, also in presence of standard cables' shielding. These examples are not simply extending the radius of the spherical space-time region, the “domain” (or, *Environment*) in which our measurements take place, well out of the assumed

perimeter of the Food and Beverage Factories. This, because what really performs the *inspection* function in the over 100000 Electronic Inspectors into Food and Beverage Bottling Factories are, nearly invariably, atoms of Silicium. Atoms of Silicium into the billions of transistors, themselves part of Integrated Circuits processing signals mainly incoming by CMOS- and CCD-cameras. Several stages of amplification, filterings and comparisons of these amounts with parameters, are the essence of the inspection process. A process finalised to *Binary Classification*, typical task for Quantum Computers processing qubits rather than bits and a long chain of nonclassic measurement stages.

Tunnel-effect a way toward a technological breakthrough

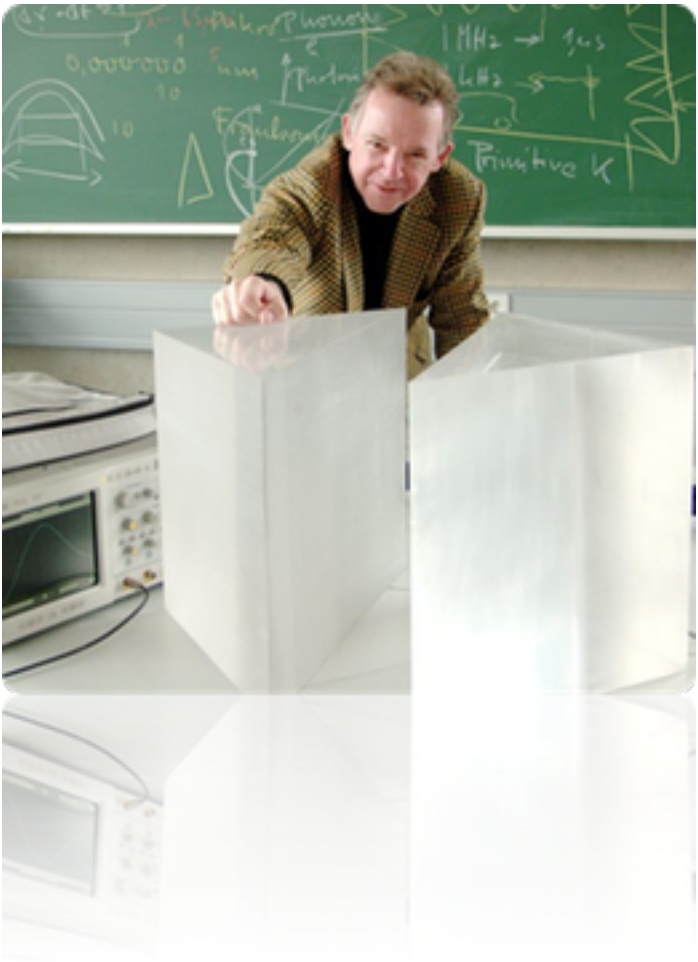
A practical example of the many logical and experimental threads which carried to this modern scenario, given by the non-classic quantum mechanical Tunnel-effect discovered in 1958 by Esaki. Below, on right side a practical application, the Tunnel-effect diode and its nonlinear characteristic current-voltage curve. The animation below shows the time-evolution of the wave function of the electrons in those atoms of Germanium building up this electronic component. Electrons making what Classic Laws of Physics considers impossible, passing through a barrier of potential. Heisenberg’s Uncertainty Principle allowed and made sense of this expected behaviour yet decades before the experimental discovery. What has been discovered later that the Tunnelling effect is ...too fast.

Thorough testing by several Laboratories, the first of them that of the prof. Günter Nimtz at Koeln University, Germany (see image on right side), at different frequencies and for different kinds of particles, allowed the determination of superluminal speed across the barrier.

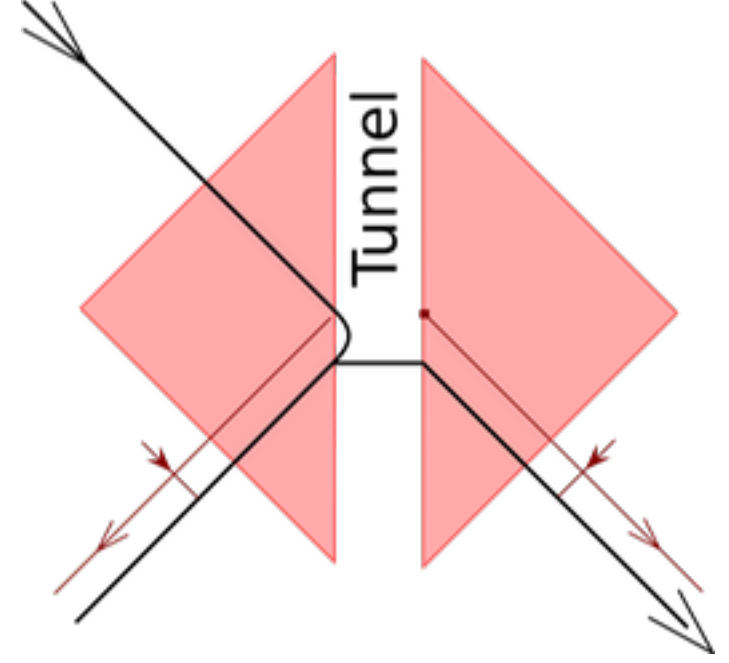
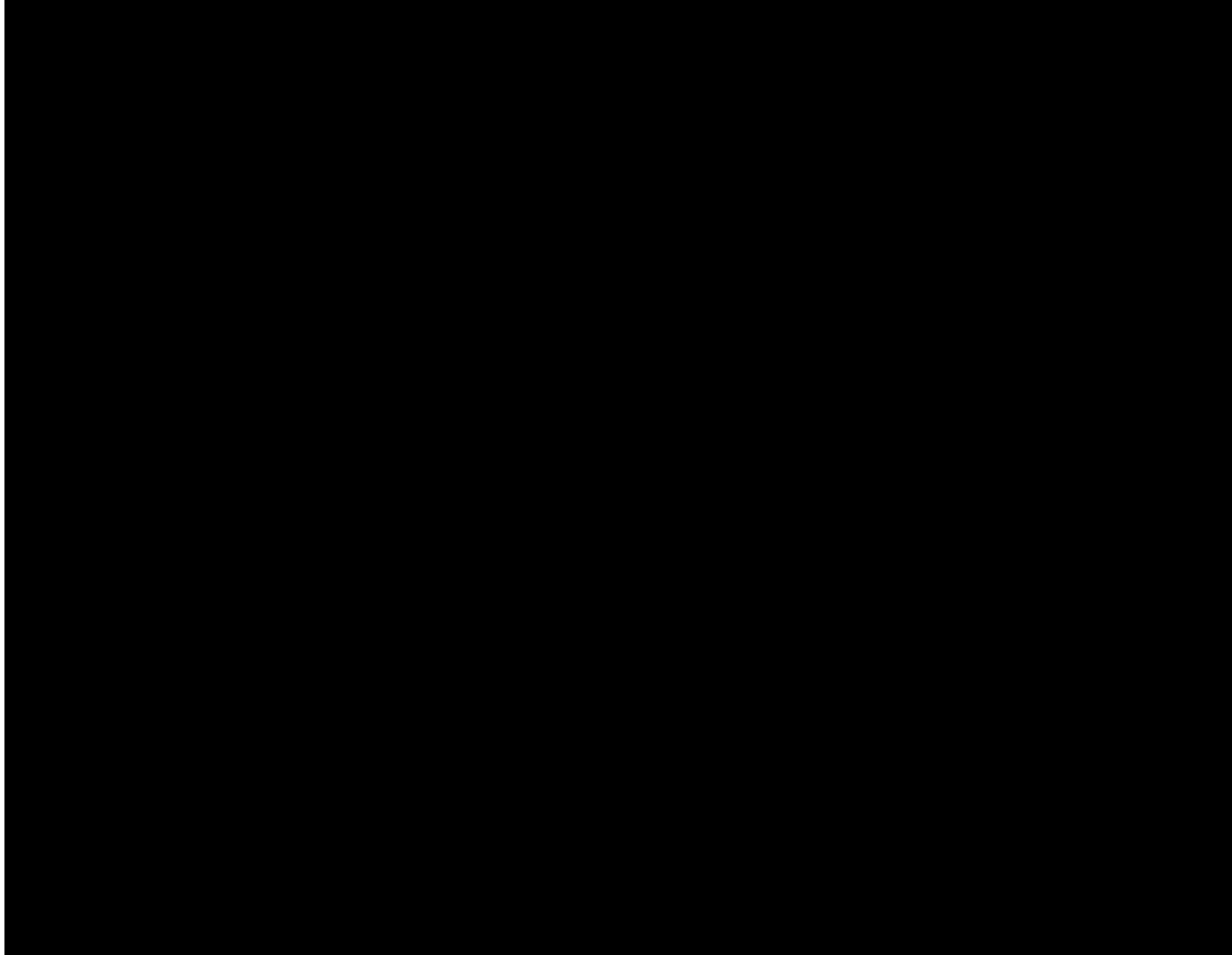
As an example, the graph below shows two microwave pulses at the same frequency of 8.2 GHz travelling through:

- (1) air (light violet)
- (2) a barrier (dark violet);

the latter traversed the same distance ~ 1 ns faster, a speed 4.7 c, say nearly five times faster than light speed in vacuum (299 792 458 m/s).



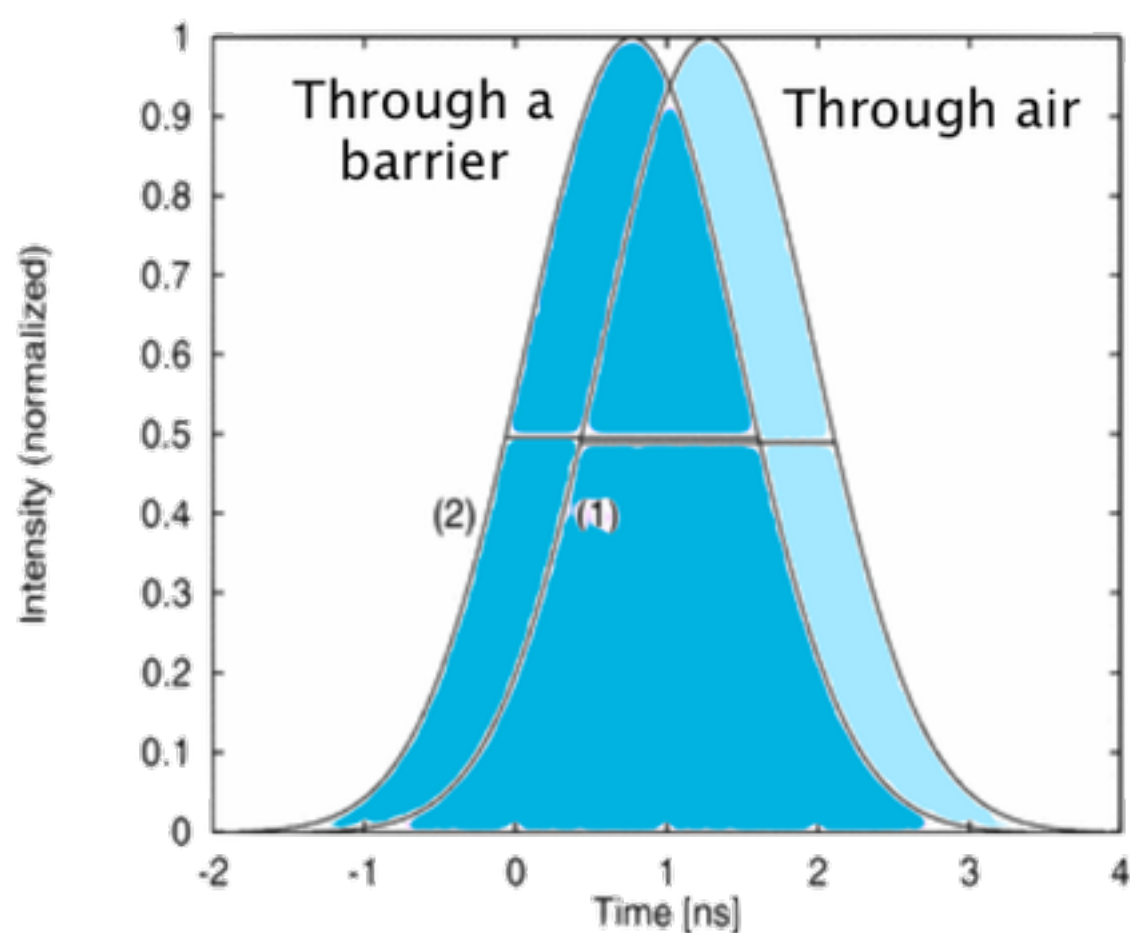
▲ **Prof. Günter Nimtz. His impressive breakthroughs are confirmed by an amount of other independent experiments and theories. Some of them, of Bell-Aspect type about Entanglement, verified until 30 σ , ...thirty standard deviations ! (image published with written permission of prof. Günter Nimtz, 2014)**



▲ Nimtz and Stahlhofen double prism experiment of 2006. Photons can be detected behind the right-hand prism until the gap exceeds up to about one meter (image credit Jochen Magnus, 2011)

▲ Evolution of the electron wave function through a potential barrier. The animation renders what let the Tunnel-effect diode (figures on right side) be so fast with respect to the other components: the Heisenberg Uncertainty Principle. The central white colour vertical bar is the potential barrier Classic Physics considered impossible to breakthrough. If we assume the video showing a single electron in a single Universe, then frequent superluminal propagation of the wave function implies paradoxical situations, synthesized in violations of the basic postulate of Relativity: the existence of a maximum limit speed. Tunnel-effect diodes are simply 'too fast' to be existing in a unique instance. What seems to cross the barrier five times faster than light, when considering that the electron coexist in several interfering branches of a common tree-like structure, is with today a few residual doubts only a side effect of our perspective

A deviation out of any possibility of explanation in terms of mere *statistical fluctuations*, say the fluctuations implicit in all physical measurements, whose true origin we are not here detailing.



▲ Tunnel-effect hints to an interpretation of the events described by the Quantum Field Theory. In the example on left side, photons crossing air (1) or a barrier (2). When crossing the barrier they reach the opposite side ~ 1 ns before those which crossed the air, say 4.7 times faster than the maximum speed of light in vacuum postulated by Relativity (abridged by G. Nimtz, 2006)

A deviation *superluminal* if, and only if, the wave packet propagated is a unique instance existing in a single universe, say the classic point of view, dated 1905-1915, of the Special and General Relativity theories. On the opposite, no violation at all of Relativity (no superluminal propagation) postulates if what we are integrating into our *measurement* are a multitude of superimposed instances of the same object with multiversal existence in several and mutually interfering branches. Each one instance of the same object in a slightly different *Environment* what, after Decoherence discovery, is the modern meaning for *World*.

Wave packets which, because of the:

- Heisenberg’s Uncertainty Principle;
- linearity of the Quantum Mechanics wave functions which let the semiconductors switch and amplify;

are irreducibly superimposed multiversal objects, behaving dependently of what is happening elsewhere. Tunnel-effect can only be understood within the nonclassic point of view of Quantum Mechanics where, like a dam, the Uncertainty Principle separates Classic and Modern ideas we have about the physical world.

Massively confirmed evidence

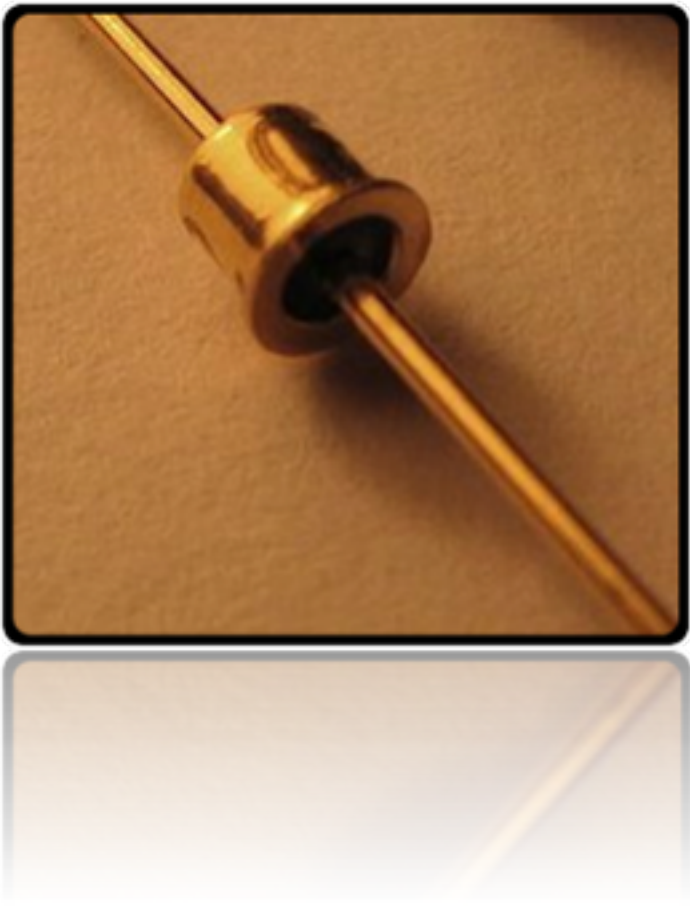
The concept of *propagation speed* makes sense if Time exists as a fundamental, because the concept of Speed derivates by those of Space and Time. Then, the conundrum is Time. We saw elsewhere the General Relativity assumption about the time-ordered sequence of submanifolds (slices or, leaves, of the manifold \mathcal{M}) constituting a Foliation, whose details and properties we examined here. (../Trigger-Physics/index.html) In this framework, what clocks measure is proper time s along their own worldline γ , maintaining coherence with the General Covariance Principle over which Relativity theory is based.

1967

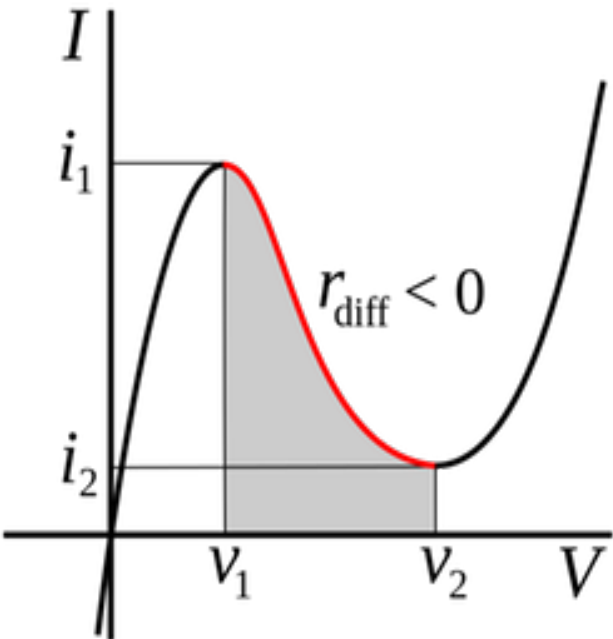
In 1967 the Wheeler-DeWitt equation was capable to join General Relativity and Quantum Mechanics:

$$\hat{H}(x)|\psi\rangle = 0$$

and, what is truly relevant, without any reference to the Time. How ? In brief, the Ψ term above is the superposition of all of the elemental wave functions related to all of the existing wave packets. More, from the point of view of that superposition, no time evolution exists at all. On the opposite, correlated sets of wave packets part of the superposition witness the initial condition effect historically named *Time*.



▲ Tunnel effect diodes sport extremely high speed of operation, ~ 1 THz (1 terahertz equals 1000 GHz). This results from the fact that Tunnel diode only uses majority carriers, e.g., holes in an N-type material and electrons in a P-type material. The minority carriers slow down the operation of a device and, as a result, their speed is slower



1983

In 1983 Don Page and W. T. Wootters showed how entangled particles could be used in a Quantum Physics test, to see that the time-ordered sequencing (of the relativistic spatial foliation \mathcal{M}) is in the reality only felt by objects correlated with others because of Entanglement.

Entangled couples of particles:

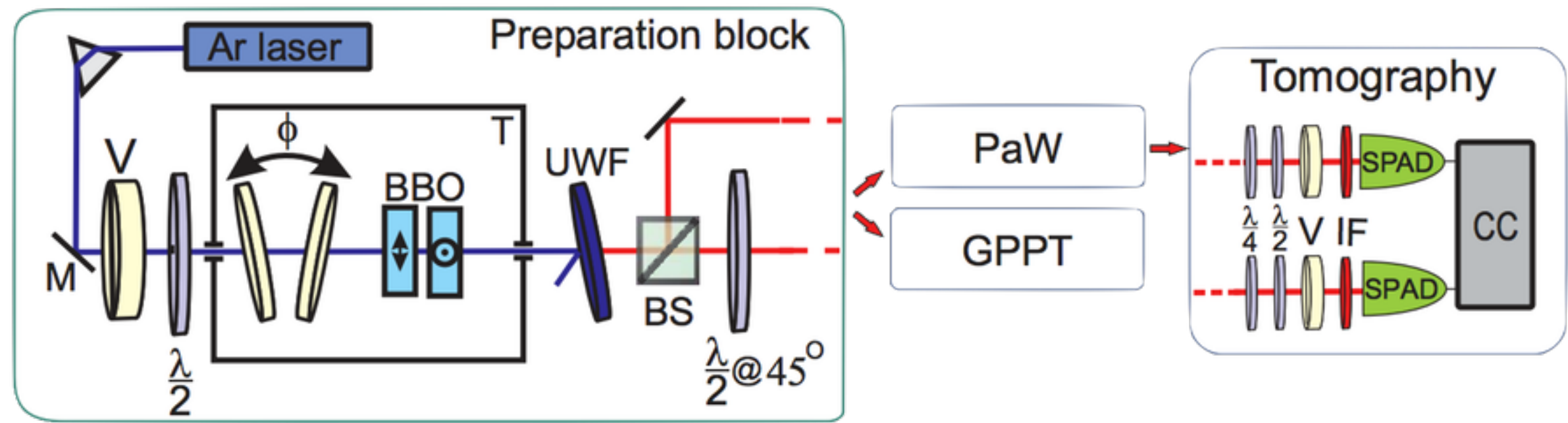
- have notoriously one of their properties strictly related and are unrelated to the Environment, until a measurement is accomplished on one of them by a third party or the Environmental Decoherence prevails;
- also when widely separated in the 4-D ordinary space-time, they continue to share the same small Hilbert space;
- are explicitly cited by the Relative State formulation of Quantum Mechanics.

Objects related to the Environment feel the effects of Time: Thermodynamics being a relevant example.

2013

The experiment thought by Page and Wootters involves Entangled photons. It had been first time executed along 2013 by a multinational team guided by Ekaterina Moreva. The figure below shows the Optoelectronics layout of the test, including beam splitters, lenses, filters, plates and LASER light commonly adopted into camera-equipped Electronic Inspectors. It has allowed to form an entangled state of the polarization of two photons, one of which is used as a clock to gauge the evolution of the second:

- an "internal" Observer that becomes correlated with the clock photon sees the other system evolve;
- an "external" Observer that only observes global properties of the two photons can prove it is static.



▲ Optoelectronics' layout allowing to form an entangled state of the polarization of two photons, one of which is used as a clock to gauge the evolution of the second. To an "internal" Observer that becomes correlated with the clock photon the other system appears in evolution, while to an "external" Observer that only observes global properties of the two photons, it looks static (figure credit Moreva, et al., 2013)

▲ The negative differential resistance of the Tunnel-effect diode, in a current-voltage graph. The nonlinear and nonclassic feature of the diode identified in the red coloured negative differential electric resistance, base of its impressive speed performances. The tunnelling effect is inherently very fast..., too fast when we consider that recent thorough testing has determined superluminal speed. Superluminal if, and only if, the object is a unique instance existing in a single world

The recently published results confirm the analysis given in 1983 by Don N. Page and W. K. Wootters: **Time is an emergent property, deriving from quantum correlations (namely, Entanglement), and not a fundamental of Physics.** Then, now that it is established on the dual theoretical and experimental base that Time is a derived concept of Physics, the superluminal speed of the experiments developed on Tunnel-effect, has to be moved from the paradox rank to that of unavoidable effect. We cannot calculate any speed, where no Time evolution exists.

Following the Quantum Theory of Measurement, each one time a "good measurement” happens, a correlation between two systems and respective wave functions, a new history branches itself out of the others. This process, introduced by Everett (1957), later adopted by many eminent physicists.

Between them, the nobelists:

- Richard Feynman,
- Stephen Weinberg,
- Alan Guth,
- Murray Gell-Mann,

and also some of the most brilliant minds of Physics like:

- David Deutsch,
- James Hartle,
- John A. Wheeler,
- Stephen Hawking,
- Leonard Susskind,
- Lev Vaidman,
- Avshalom Elitzur,
- Yakir Aharonov,
- Dieter Zeh.

The idea clearly explained in DeWitt (2004, pages 138-144). That’s why no violation of the light limit speed c exists in the Tunnel-effect: the new Events are observed along a new branch, a new history, and no referral to prior measurements and results make sense to apply. Since two decades this is the mechanism conceived underlying correlations superior to 30σ (thirty standard deviations !) in the worldwide Bell-Aspect experiments studying Entanglement.

Also, it allowed decades ago to understand that the mechanism effectively prevents causal violations effects of an hypothetical topologic structure like the Einstein-Rosen bridge (also known as *wormholes* or *Closed-Timelike-Curves*, CTCs). Einstein-Rosen bridges are implicit in the General Relativity theory. However, until recently the basic idea of CTCs hitte

The new concept of Measurement, as a matter of fact, prevents CTCs from creating paradoxical causal violations at all scales:

- microscopic;
- macroscopic.

Considering all this, Quantum Mechanics is today backing the coherence of General Relativity.

Showing that these extremal scenarios of another theory are not in contradiction with its basic assumptions. Entanglement idea derives by what in 1935 Einstein, Podolski and Rosen figured what at first sight appeared as a flaw into Quantum Mechanics, one proving at least its incompleteness. It later resulted that the single-world classic point of view of General Relativity

The term Multiverse has no relation with the known "Parallel Universes”, made popular by Science-Fiction. “Parallel" means not interacting or ambients causally disconnected, say no exchange at all of Signals and Energy. Multiverse is nearly the opposite: a superposition of all of the mutually interfering wave packets, corresponding to the wave functions of all objects. Renamed “Multiverse” to mark the conceptual difference. A tree-like structure from our point of view. A multiply-connected object, as seen by Topology point of view. Several coexisting instances of each one object, each one part of a slightly different ($\delta = 1$ bit) Environment.

"Time is an emergent property, deriving from quantum correlations and not a fundamental of Physics”

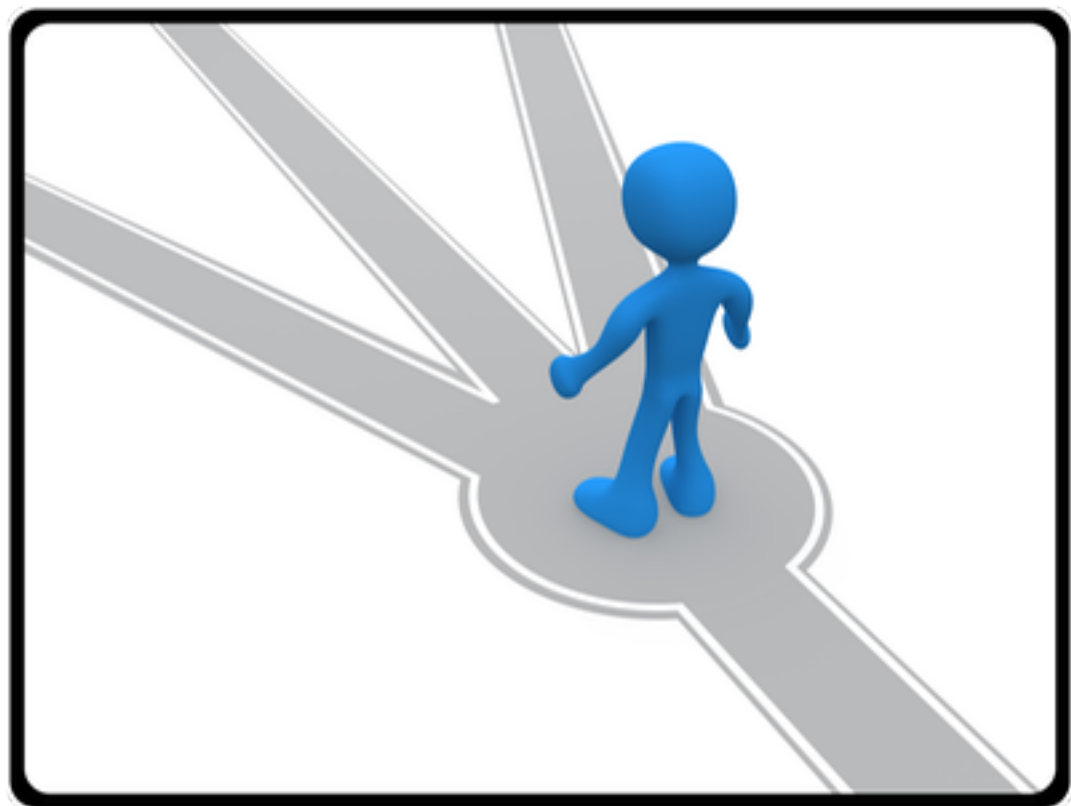
is an approximation.

Each “good measurement” establishes a new additional thread along the sum of all of the yet existing histories. In this framework of correlated, non-interacting, systems it is explained (see Everett in eds. DeWitt, *et al.*, 1973, pages 78-83) why and how they are implicit consequences of the Quantum Theory of Measurement, however incomprehensible they may appear as seen by the classic approximation.

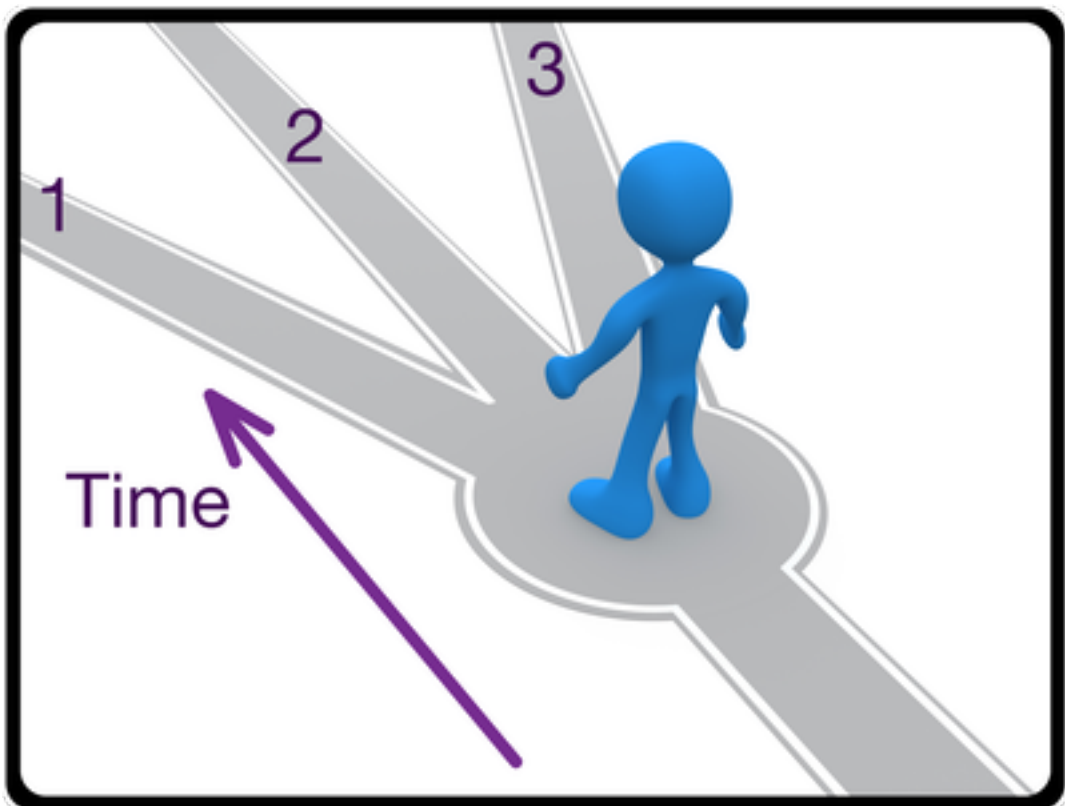
The two figures below synthetise the situation:

- **left side**, the **modern** paradigm, where Time does not exist any more. Measurements as a natural process continuously happening and each *possible* measurement's result is *actual*: the starting point of a new branch of the general history;
- **right side**, the **classic** point of view today disproved by theory and experiments. An initial condition is perceived like *Time* by apparatuses and Observers into some of the branches, which are have no information about the content of the other branches of the history. Time, in the reality, a proved effect of the Entanglement condition of apparatuses and Observers.

Each “good measurement” establishes a new additional thread along the sum of all of the yet existing histories



Modern



Classic

Large scale effects of a change of paradigm about the Measurement

We saw here that in the Electronic Inspectors, ([../Trigger-Physics/index.html](#)) the simplest measurement subsystems named Triggers are constantly labelling the (or, applying an identification to) objects to their position in the space-time, coarse graining (enclosing) them into macroscopic Shifting-Register's cells. We have shown how an Event can be associated to the label of a single slice (or, leaf) in a vast foliation. There is no fundamental distinction between measuring devices and other physical systems. What Triggers differentiate are the

identities of the objects. Triggers are the most elementary kind of inspection which can be conceived in a Bottling Control. A measurement is a special case of interaction between physical systems, an interaction which has the property of correlating a quantity in one subsystem with a quantity in another.

With reference to the formalism of the modern version of the Principle of Superposition presented here ([../Trigger-Physics/hugh-everett-iii-dissertati.pdf](#)), is cleared that an interaction is a measurement (pages 54-60) if it satisfies three requirements:

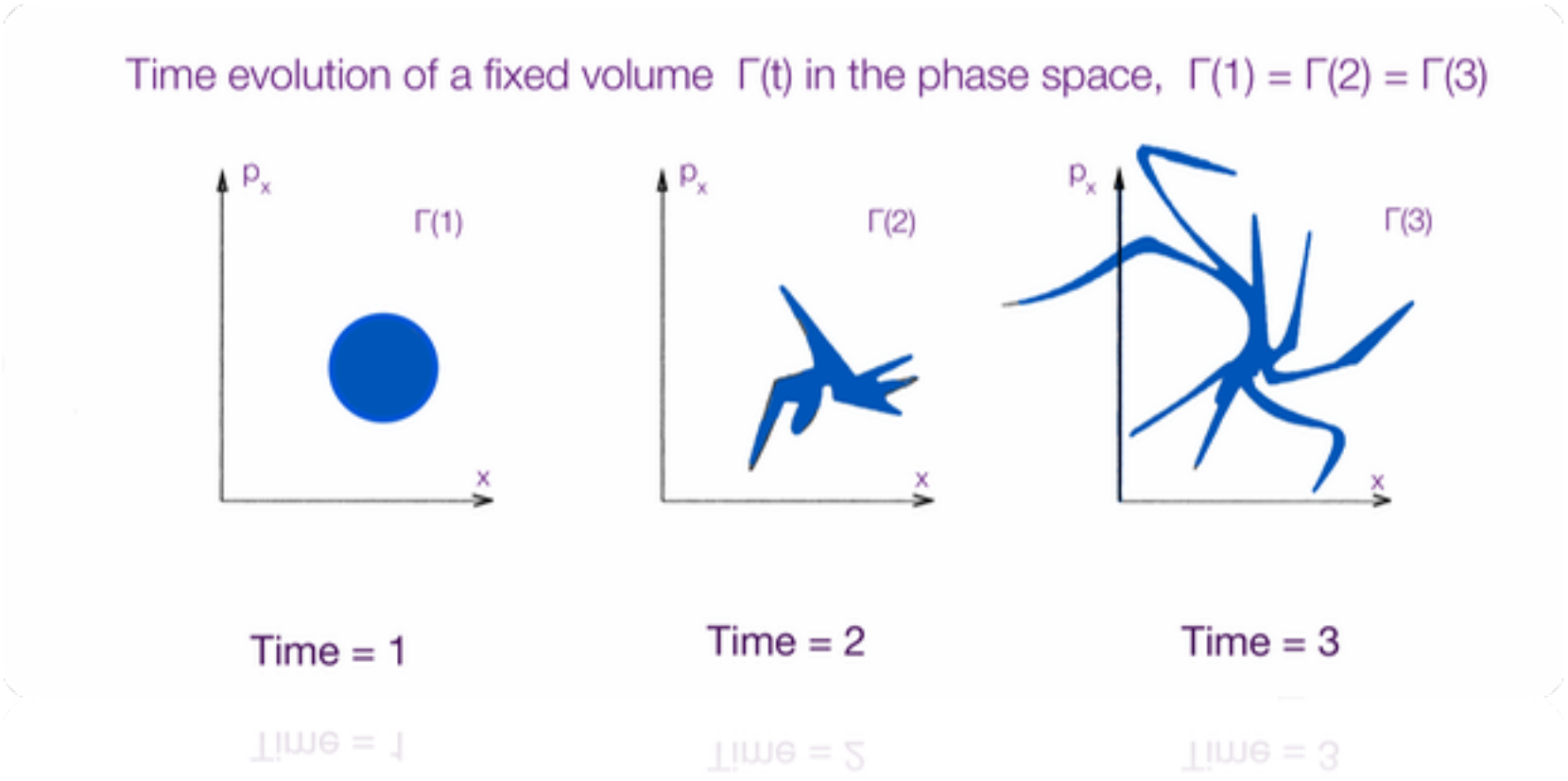
1. the measurement is associated to a fixed interaction H between systems;
2. the measured quantities are the limit of the instantaneous canonical operators, as the time goes to infinity. Our common measurements subjected to finite times are approximate and approach exactness as the time of interaction increases indefinitely;
3. if the fixed interaction H is to produce a measurement of A in S_1 by B in S_2 then H shall never decrease the information in the marginal distribution of A . In other terms, if H is to create a measurement of A by correlating it with B , we expect that a knowledge of B shall give us more information about A than we had before the measurement took place since, otherwise, the measurement would be useless.

The last requirement, on first sight obscure, regards the fact that the interaction H :

- cannot decrease the information content of the distribution of the measured object A ;
- has to increase the information we had about A before we accomplished the measurement;

is the choice which let the conservation of Probability hold true, the only choice which makes possible statistical deductions: Sturm-Liouville Theorem. A classic concept redressed under new words. Its full comprehension need an aid to intuition, aid which may arrive by the following two figures referred to cases with two and three dimension. In Mechanics and Thermodynamics there is a precise signification when saying that Information is never lost by a closed system.

Please refer to the two figures below, showing in two and three dimensions the time evolution of a defined volume in the phase space. The volume of the region $\Gamma(t)$ represents the information we have about a system at three successive times $t = 1, 2, 3$. Visibly, the information does not increase. Sturm-Liouville's Theorem holds its full validity also in those mesoscopic and macroscopic space-time scales where the Optoelectronic devices in the Electronic Inspectors are sensible.



▲ **Signature of John Von Neumann, who created much of the Quantum logic and terminology**

Basic Quantum Terminology

Coherent, typically applied to a system, in modern Physics is a synonymous of **superimposed**. In this sense, superimposed (or, coherent) are the orthonormal eigenvectors constituting a base for the wave function Ψ , representing an object, however complex or massive may it be.

Then, **decoherent** means reduced by a measurement to one definite value (*eigenvalue* of the *eigenstate*), the only one we perceive in the multitude of alternatives.

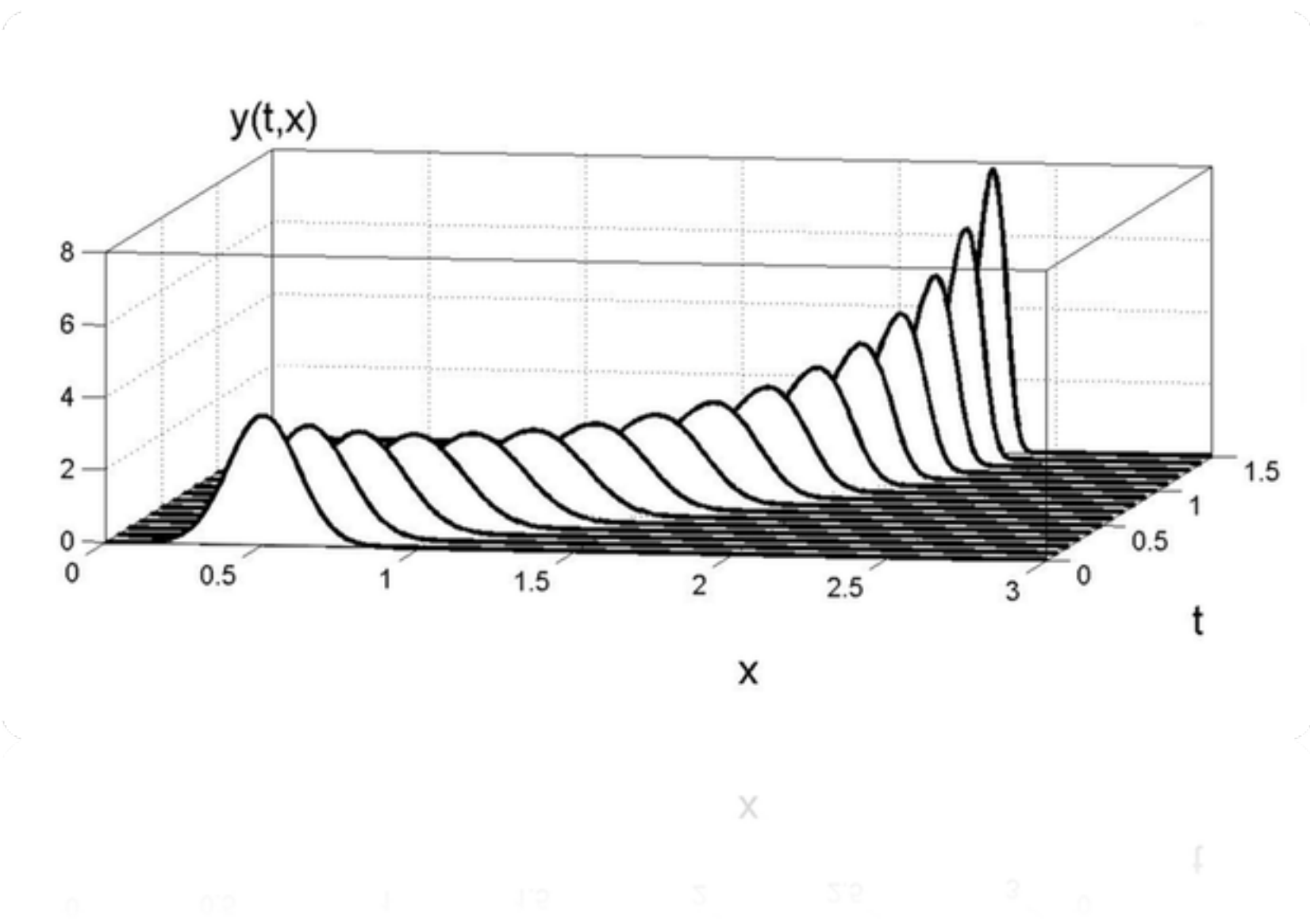
Eigen means “characteristic” or “intrinsic”.

Eigenstate is the measured state of some object possessing quantifiable properties like position, momentum, energy etc. The state being measured and described have to be observable (e.g. like the common electromagnetic measurements of Bottling Controls), and have a definite value, called an **eigenvalue**.

Eigenfunction of a linear operator, defined on some function space, is any non-zero function in that space that returns from the operator exactly as is, except for a multiplicative scaling factor.

On left side: evolution of a defined volume $\Gamma(t)$ in the phase space. The region $\Gamma(t)$ represents the information we have about a system at three distinct and successive times $t = 1, 2, 3$. Visibly, the information we have does not increase. Liouville's Theorem holds its full validity, included those mesoscopic and macroscopic space-time scales where the Optoelectronic devices in the Electronic Inspectors are sensible (abridged by image Susskind, 2005)

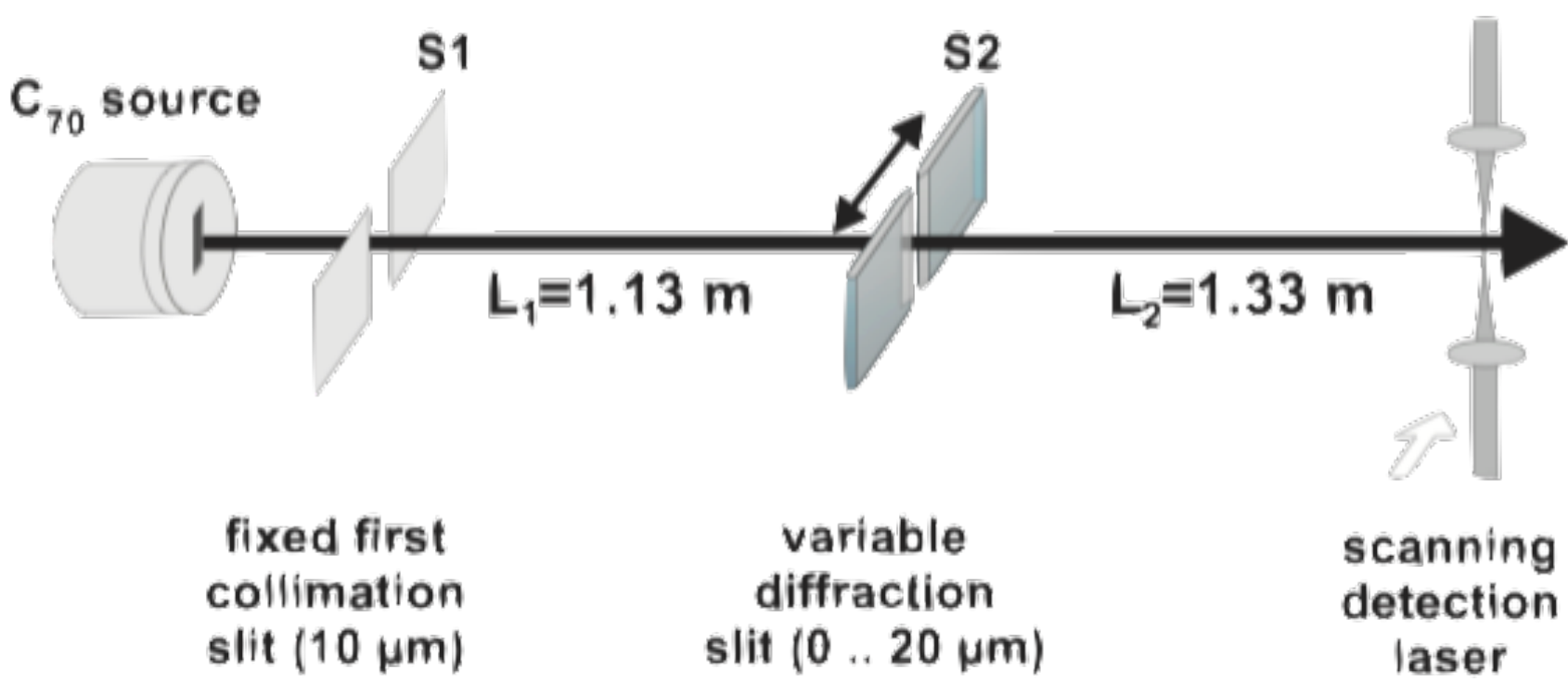
This is the origin of the third constrain appearing above, about the fact that Information cannot decrease in A but has to increase the Information we had about A before the measurement; on practice the origin of the Second Principle of Thermodynamics.



On left side: Time t evolution of a region x . $y(t, x)$ is their Liouville function. The spreading of the Liouville function with time made evident by the fact that the graphic is not monometric: 1 cm on the y axe equals 4 on the x axe. Liouville function and its underlying concepts regarding the phase-space operates wherever: we'll encounter it again as a useful tool to evaluate what rejects' rates may be expected after changing an inspection's sensitivity, given initial conditions

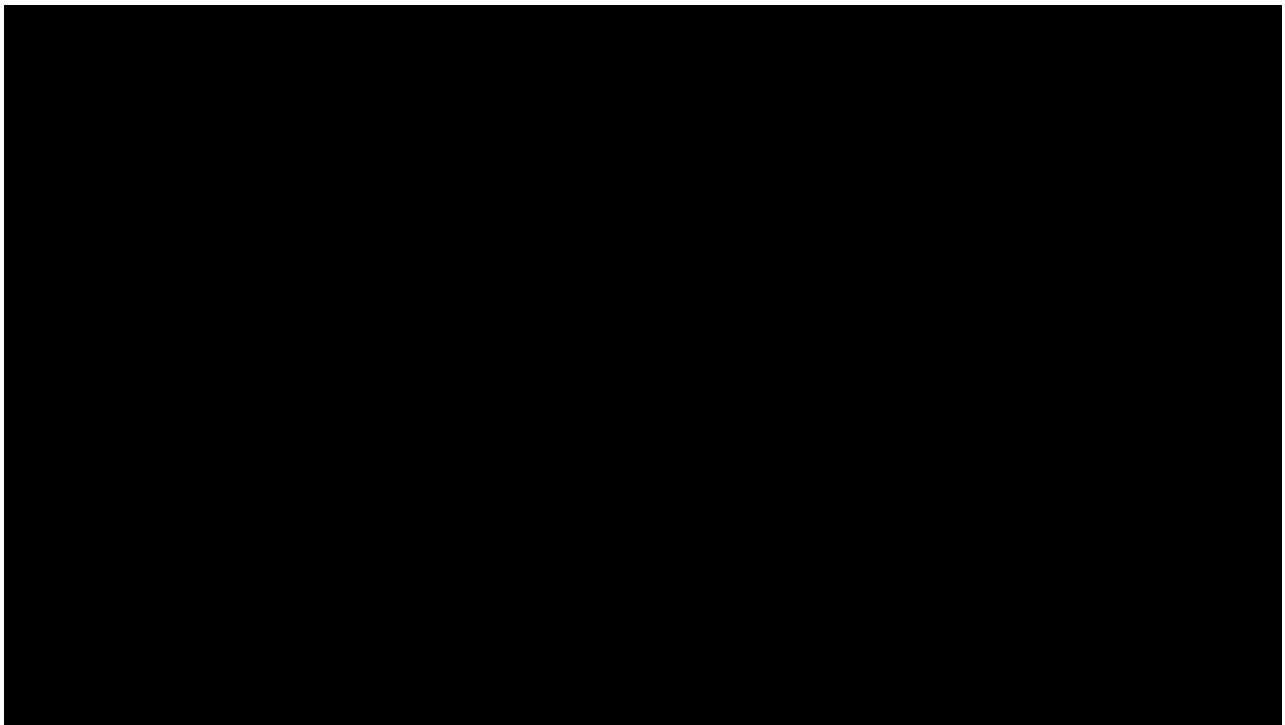
Mesoscopic scale:
an arena for experimental verifications

In 2010 they started to be spot objects of the size of a visible hair (~ 0.1 mm) existing in two separate places, whose separation was measured with a scanning electron microscope. Along 2012 it has been first time experimentally detected one more counter intuitive result, yet envisaged by Quantum Mechanics: LASER photons spontaneously jumping back, rather than proceeding forward in a crystal lattice.



▲ Setup used in 2001 by Zeilinger *et al.* which allowed to verify that also macromolecules entails fully their properties in the non-classic domain of Quantum Mechanics and respect the Heisenberg Uncertainty Principle. Fullerene C70, is an allotropic form of Carbonium 70 atoms (figure abridged by Zeilinger, *et al.*, 2001)

And this, not in the atomic or subatomic realm where Quantum Mechanics was only supposed to act. Rather, on the same mesoscopic scale of the semiconductors' junctions part of the phototransistors of which are equipped nearly all of the photo-sensors used as Triggers by the most Beverage Bottling Controls. A new paradigm is arising, one whose powerful fruits are commercial applications as different as the Quantum Computers, simultaneously parallel processing in several other Universes, now used by companies like Google, Inc. or Lockheed-Martin Corp. and academic researches sponsored by the Society of Lloyd's yet in 2007. Why these private companies should be investing money in something, at first sight, seemingly theoretical ? The answer, in some way, is related to the discovery of *Decoherence*.



▲ Close up on the molecule of Fullerene C60, an allotropic form of Carbonium with 60 atoms. Visible the isosurfaces of ground state electron density. Discovered in 1990, was the first used after 1993 to test Decoherence in the mesoscopic scale of dimensions. The Van der Waals diameter of the molecule C60, accounting also for the thickness of the electronic clouds around nuclei, is 1 nm

Close-up on Decoherence

"*Decoherence:*
process that classicalizes a quantum phenomenon, so that its former wavy character disappears"

Triggered Events lie in the space-time and energy boundaries separating the fields of applica-tion of Classic and Quantum Physics. We all agree that macroscopic objects are composed of collections of microscopic, like molecules and atoms. As a consequence, Triggered Events are finely rooted there, in the microscopic scale of distances. But, we all are convinced to see *individual Events referred to individual Objects*. The Objects to whom we are referring being always and only human-, space-, time- and energy-proportioned objects.

No one, in absence of instruments, is capable to discern:

- grains of dust whose diameter is < 0.01 mm;
- Events separated by a time interval < 0.001 s;
- radiant energy < 0.1 nJ;

because our eyes, and the neuronal system supporting their function, are not biologically developed for that. But, in the end, these limits does not matter that much. Since 1985 they are known the factors which let the multitudes of paths above described, fruit of Feynman’s own intuition, be reduced to the individual alternative we are experiencing. An introductory definition for this modern concept is the process that classicalizes a quantum phenomenon, so that its former wavy character disappears. **Decoherence is the theory of universal Entanglement: it does not describe a distortion of the system by the Environment, but rather a change of state of the Environment by the system.** The Environment includes a multitude of air molecules and photons, mainly at thermal frequencies. Imagine a macroscopic body as massive as a Bowling Ball like that in one of the figures below, on right side. In this case, scattering of photons or atoms off such a macroscopic object, even very small dust particles or macromolecules, causes no recoil. But, this inefficiency in the measurement results over compensated by the multitude of scattering Events, occurring in our daily life and industrial Environmental conditions, even along small time intervals, say:

- atmospheric pressure: ~1 bar;
- temperature: (-30 - 60) °C;
- relative humidity: (0 - 100) %.

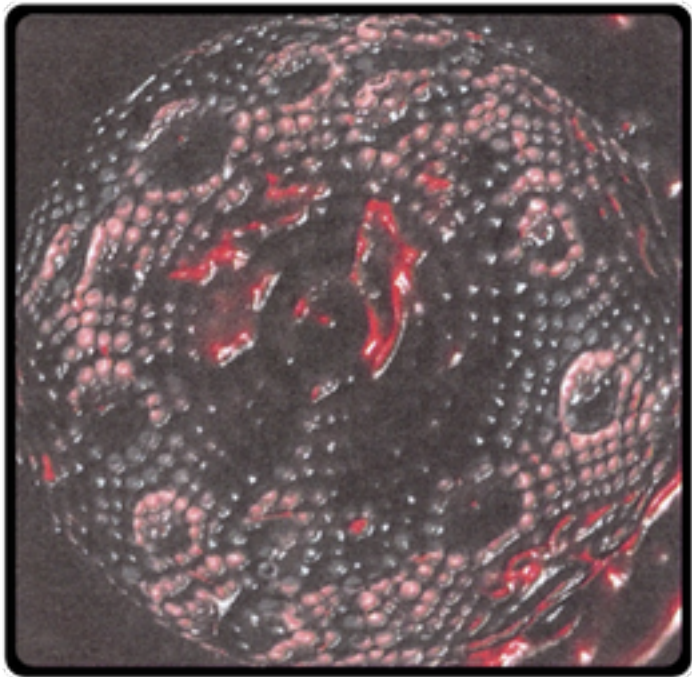
Young’s experiment with and without air

The two figures below representing the Young double-slit experiment with and without molecules of gas (air), interposed along the paths of electrons.

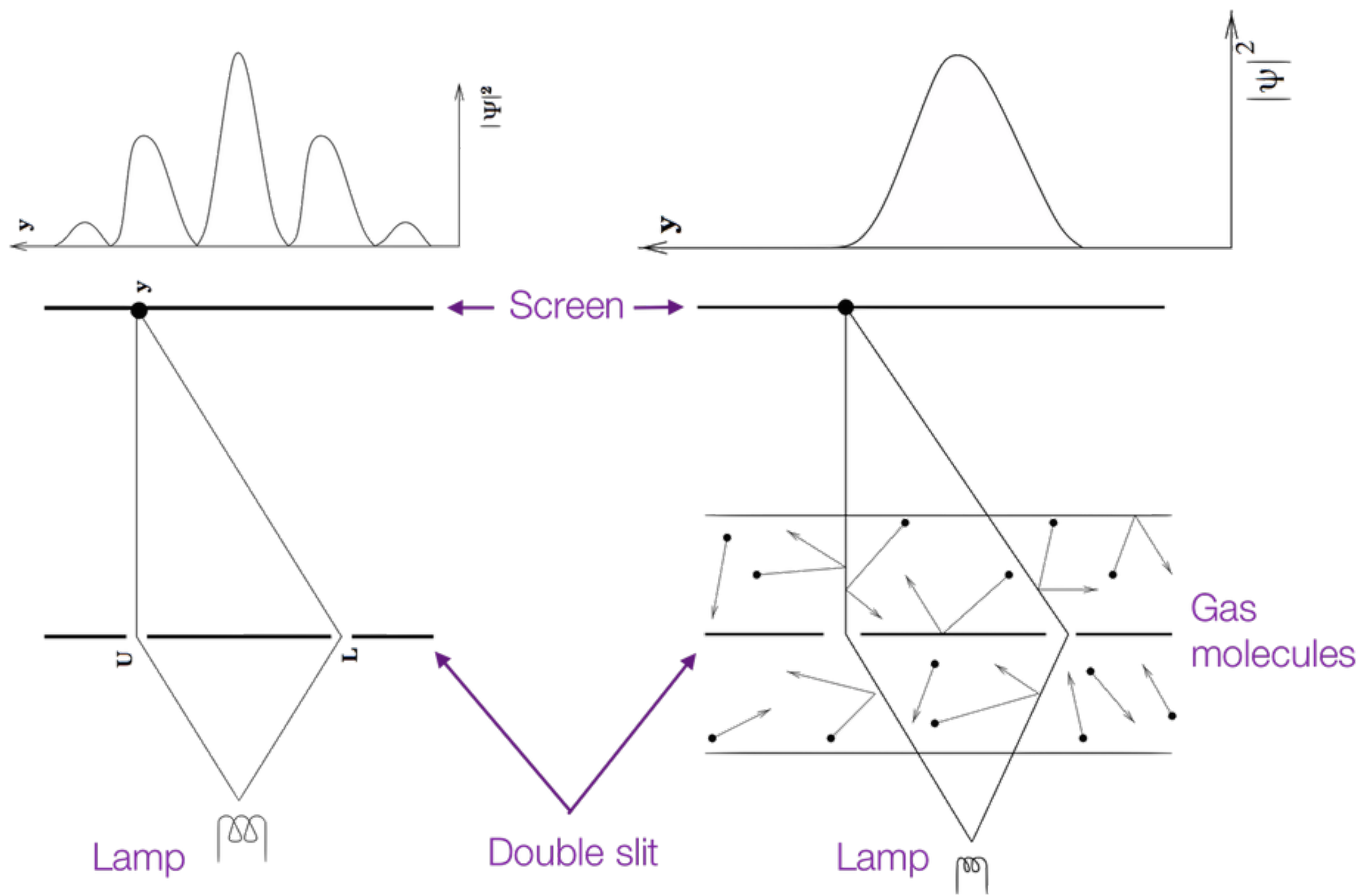
Two completely different distributions of the hits counted on the following screen:

1. on left side, in a vacuum;
2. on right side, with the gas molecules of air.

Decoherence is what impedes us to see all objects in their superimposed reality. It is mainly due to the collisions between the molecules of air and the electronic clouds around each one atom. These collisions carry away the phase correlations between the histories where the electron arrived at several other points. The next two section shall detail what is detected with and without interposed gas. It’ll be accounted how Decoherence phenomenon, discovered in 1970, was hiding the direct sight of the true constantly happening behaviour of the matter and radiation, first detected only in 1989.



▲ **Mesoscopic scale of dimensions. Tungsten individual atoms directly sighted in this image obtained in 2008 of the tip of the sharpest Tungsten needle existing. The small central red colour dot is an atom: ~0.30 nm its visible diameter. The image was obtained by mean of a Field Ion Microscope. Brighter red colour lines are an effect of smearing due to atoms' displacements along the 1 second long exposure (image abridged by Silverman, 2008)**



▲ Thomas Young's double-slit experiment, on left side in vacuum and on right side with air along the paths of electrons emitted by lamp filaments. Counting the hits on the screen, two completely different distributions arise, a difference due to Decoherence. Decoherence is mainly due to the collisions between molecules of gas and the electron, carrying away the phase correlations between the histories where the electron arrived at point y on the screen by passing through the L slit by those histories where the electron arrived at point y on the screen passing through the U slit

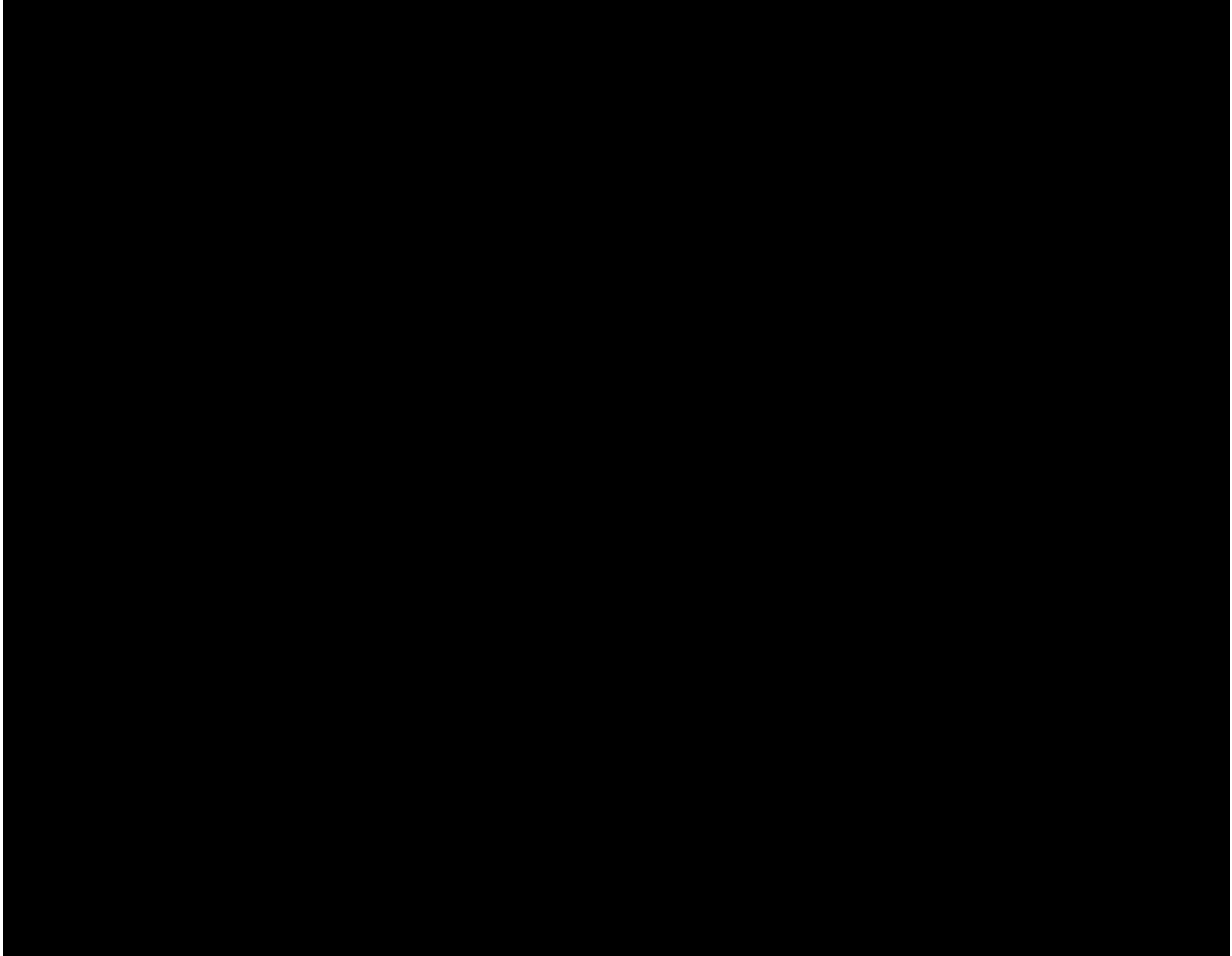
1. Double-slit in a Vacuum

Many of the ideas about the concepts of measurement, space, matter and radiation into today's academic journals originate by ideas published or however circulating decades ago.

There are reasons why this is happening. No theory can ignore the experimental evidences and these last are constantly improved. And, there are some special experiments, like Thomas Young's, first accomplished centuries ago and providing some strong clues about the *everything* reality, which had to wait centuries. The nobelist Richard Feynman decades ago imagined this when called it: "*a phenomenon which is impossible ... to explain in any classical way, and which has in it the heart of quantum mechanics. In reality, it contains the only mystery of quantum mechanics*". Feynman was writing about interference fringes appearing in the double-slit Young's arrangement when *many simultaneously electrons were fired*. "Many simultaneous" means a high probability of interference fringes due to the superposition of several electrons on the screen, something absolutely expected and normal.

But, when later, Young's experiment was first time performed with *individually fired electrons*, it was touched the surface of something much bigger than the wavelike properties of the electromagnetic radiation.

"...There are only waves and, knowingly, waves are superpositions of other waves."

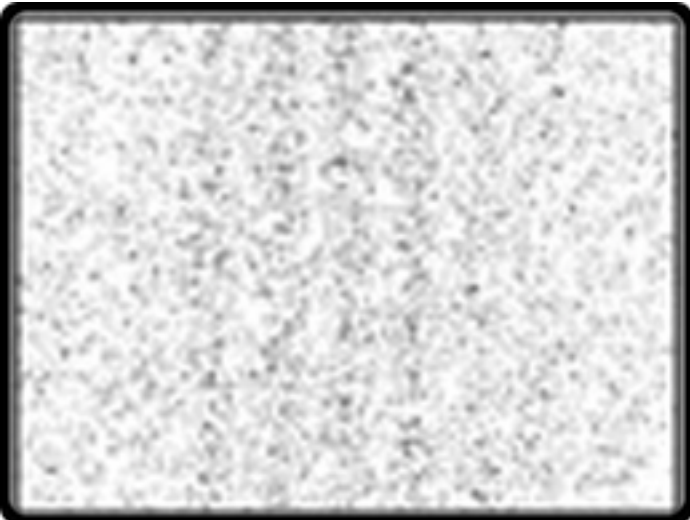


It happened in 1989. A group at the Hitachi's Advanced Research Laboratory (at Tokyo, Japan) led by Akira Tonomura developed the first double-slit system allowing to observe the build-up of the fringe pattern with a very weak electron source: *single-electrons fired on a one-by-one base* toward a double slit. What results when firing single-electrons fired on a one-by-one base toward a double slit is unimaginable. The figure below shows a schematic representation of the modifications that Tonomura made to a Transmission Electron Microscope to develop his experimental setup. Electrons are emitted from a very sharp tungsten tip (thinner than 1/1000 mm) when a potential in the range (3 – 5) kV is applied between the tip and a first anode ring; this effect is known as *field emission*. Assorted Optoelectronics within the modified electron microscope attenuates and focus the electron beam. The hits are fine-detailed by the four figures on right side.

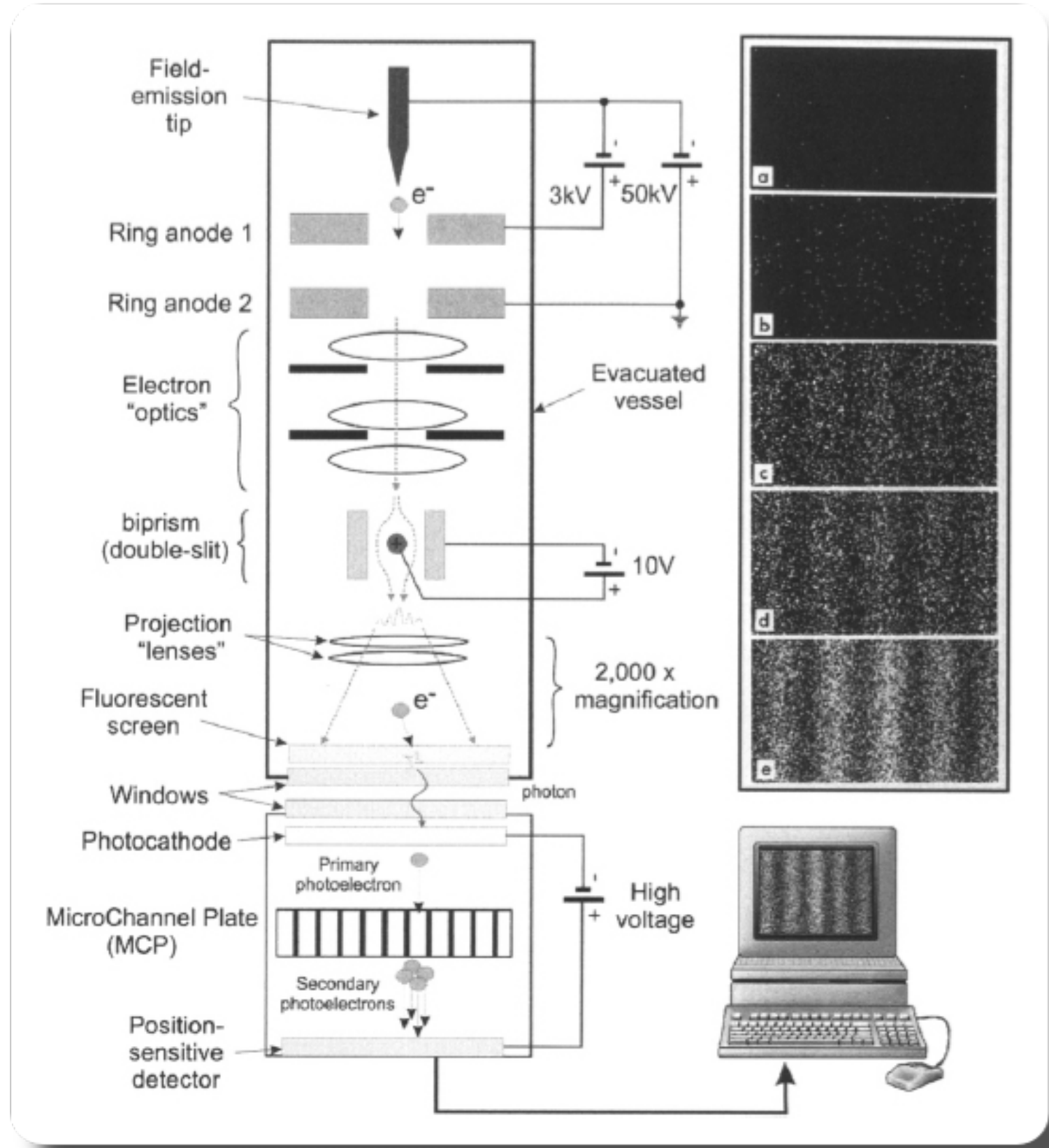
*"Field emission:
electrons are emitted from a very sharp tungsten tip (thinner than 1/1000 mm) when a potential (3 – 5) kV is applied between the tip and a first anode ring; this effect is known as field emission"*



Time = 1



Time = 2



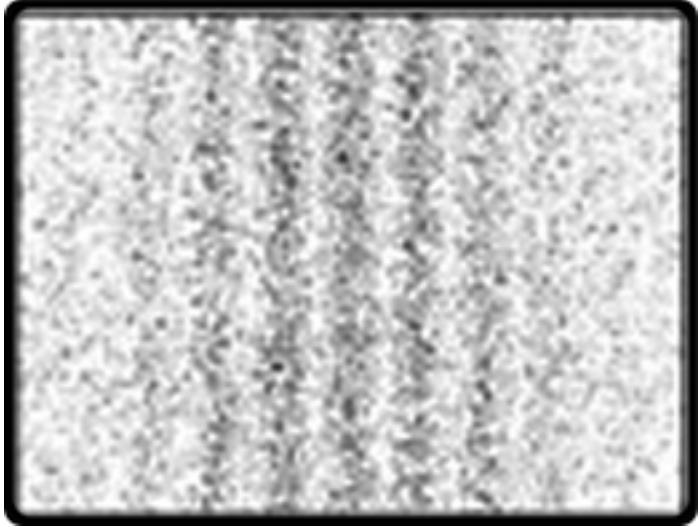
▲ **Tonomura's team experiment schematic representation. Their 1898 single-electron double-slit experiment (image abridged by Prutchi, et al., 2012)**

These show how, hit after hit, what in the start looks like mere noise, develop in the end a wave like pattern. The bright spots begin to appear here and there at random positions: these are electrons' constructive wave packets, detected one by one and looking like particles.

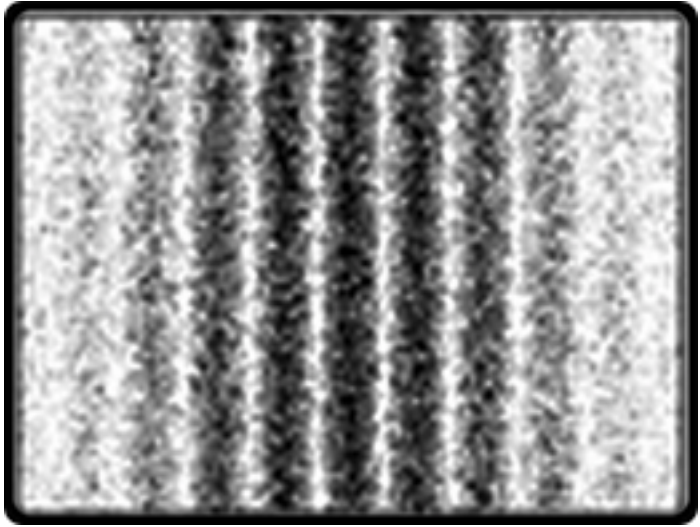
These electrons were accelerated to 50,000 V, and therefore the speed is ~40 % of the speed of the light, i. e., it is ~120,000 km/second. These electrons can go around the earth three times in a second. They pass through a one-meter-long electron microscope in 1/100 000 000 of a second. The De Broglie wavelength for the accelerated electrons is $\lambda = 0.0055 \text{ nm}$.

Interference fringes are produced only when two electrons pass through both sides of the electron biprism simultaneously. If there were two electrons in the microscope at the same time, such interference might happen. But this cannot occur, because there is no more than one electron in the microscope at one time, since only ten electrons are emitted per second. When a large number of electrons is accumulated, something like regular fringes begin to appear in the perpendicular direction shows.

Clear interference fringes can be seen in the last scene of the experiment after 20 minutes. It should also be noted that the fringes are made up of bright spots, each of which records the detection of an electron. The final resulting pattern on the screen does not resemble at all any interferential, rather hints to a corpuscular character of the objects. Although electrons were sent one by one, interference fringes could be observed. Interference fringes are expected only when electron waves pass through on both sides of the electron biprism at the same time, but nothing other than this.



Time = 3



Time = 4

▲ **Common sense defies our imagination when trying to figure how these images could be truly existing. Thomas Young's experiment was first made with light waves two centuries ago. But, since one century it is observed that firing massive particles like electrons or neutrons, on a one-by-one base, creates the same wave like pattern. And same is true also firing massive mesoscopic molecules composed by hundredths of atoms, on a one-by-one base: the same wave like pattern. Each objects fired after the precedent hit the screen, shows an interferential shape on the screen meaning that also mesoscopic bodies are, when closely looked, waves. More, or electrons have now to be supposed having their own brain (and surely they have not) or there is only a theory capable to explain how can they know what was the path choose by each one of the electrons fired before. The only theory with the necessary explanatory power is the Relative State formulation of Quantum Mechanics, also named Many-Worlds Interpretation of Quantum Mechanics (images abridged by Amelino-Camelia, Kowalski, 2005)**

Whenever electrons are observed, they are always detected as individual particles. When accumulated, however, interference fringes are formed. Please recall that at any one instant there was at most one electron in the microscope. We remark that these figures are what is detected on the screen after having been hit by *material* particles, like molecules, atoms, neutrons, or electrons. We are not speaking of objects since centuries considered wavelike, like the light (photons). This confirms that, in the reality, *no material particle exists* at all, rather only waves with different properties like energy, spin, etc.

The interpretational bifurcation reached in 1982 after Alain Aspect’s group experiment on Entanglement:

1. **Bohm-De Broglie's interpretation** explains it but only after paying the unacceptable price to postulate that light (and, gravitational interaction) does not defines the limit speed for all causal correlations: it needs to introduce tachyions;
2. **Copenhagen's interpretation** of Quantum Mechanics, has no explanation for what registered during this experiment;
3. **Everett’s Relative State** formulation, since the start included exactly what is observed;

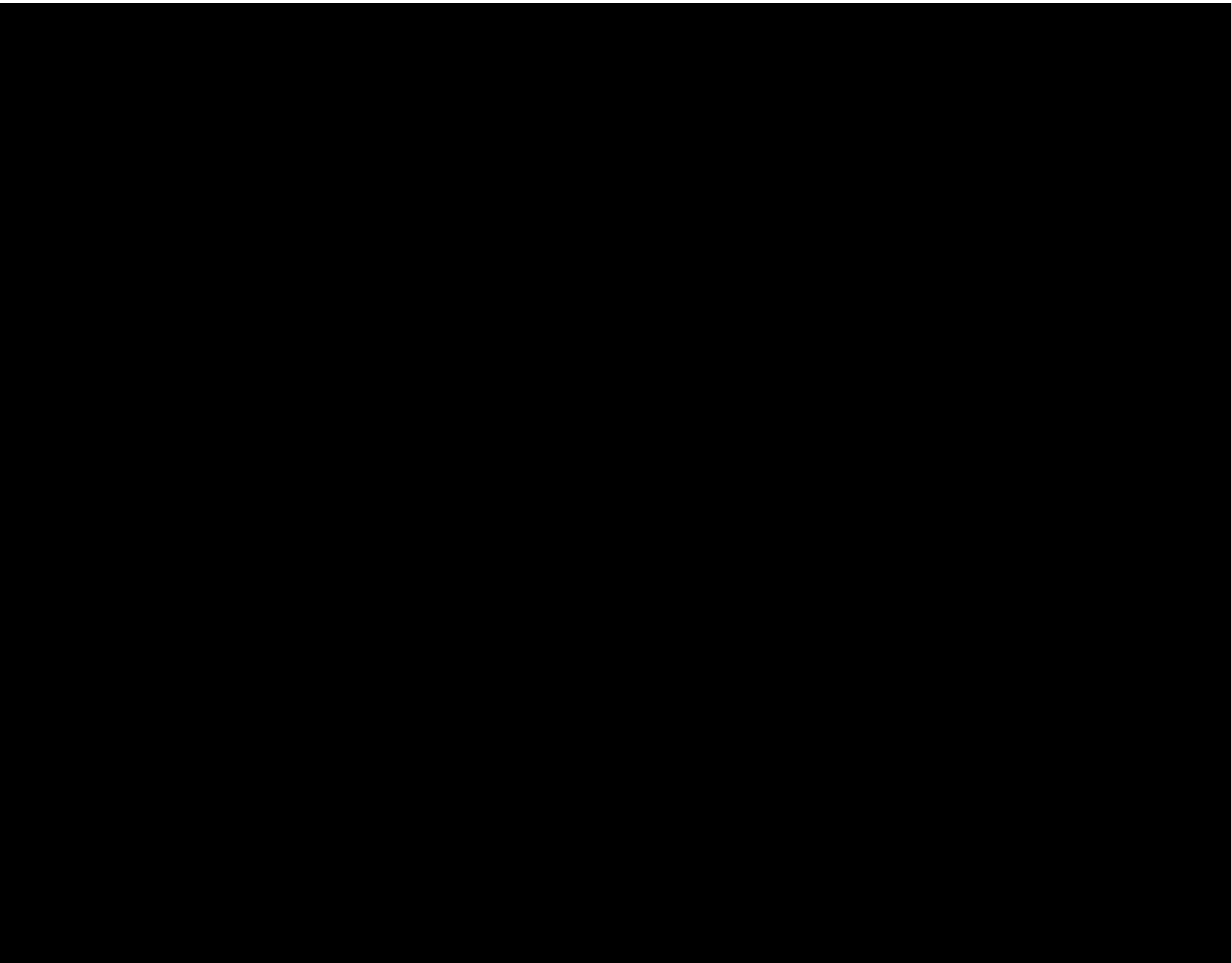
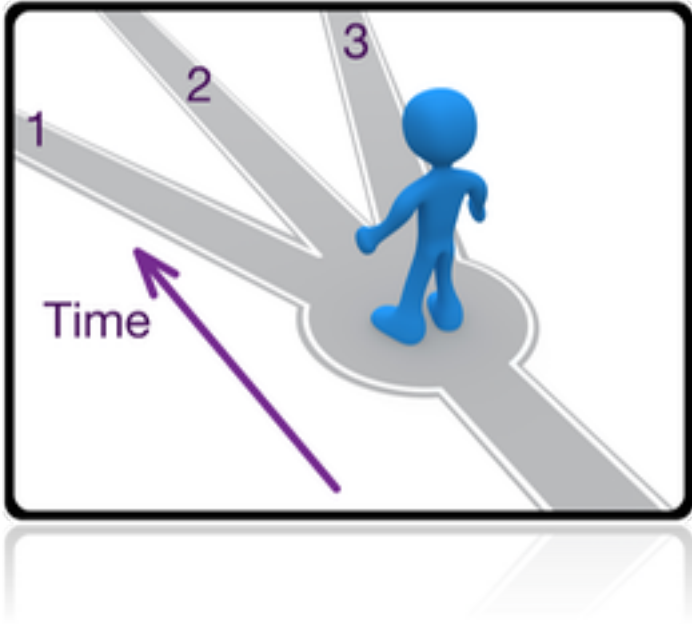
reproposed itself in 1989, this time with many more accumulated experimental evidences. The aspect of interference fringes, visible above on right side, develops itself always and also for individual particles, ...also if the molecules, atoms, neutrons, protons or electrons are *fired after* the precedently fired particle yet hit the screen. The experiment had been repeated with material bodies of progressively increasing size and mass: we are no more in the domain of particles, rather inthe mesoscopic scale close to human direct unaided sight.



▲ **61 years before it was observed, the Schroedinger equation of 1927 prefetched the result of the firing of an electron toward the slits. Wave packets are superpositions of discrete or infinite amounts of superimposed waves. The animation shows the entire process of diffraction of a wave packet in the multitude of its components, as seen by the double-slit zenithal point, perpendicular over the electrons' path**

Also mesoscopic macromolecules, including several hundredths of atoms appearing like a small grain of dust well visible by common microscopes were tested, without any change in the final result. There are only waves and, knowingly, waves are *superpositions* of other waves. More, or neutrons have now to be supposed having a brain, because it seems that they *know* what was the path choose by each one of the neutrons fired before.

Physics has since 1957 a unique theory with the explanatory power for the images on right side and, what is more important, it is not an ad-hoc one born to explain Tomomura experiment, because it was conceived 31 years before Tonomura's result. This interpretation (“The Many-World Interpretation of Quantum Mechanics”) in brief explains that all of the objects are waves and that they all are superimposed and part of a last grand superposition. Thomas Young’s experiment with matter had been extensively repeated on a worldwide base after 1989, reconfirming the veridicity of the interference fringes on side. Today they exists also cheap and valuable Optoelectronics plus software kits, to be connected to a computer thus allowing to whoever to witness and register single-electrons interferences in the two-slit configuration.



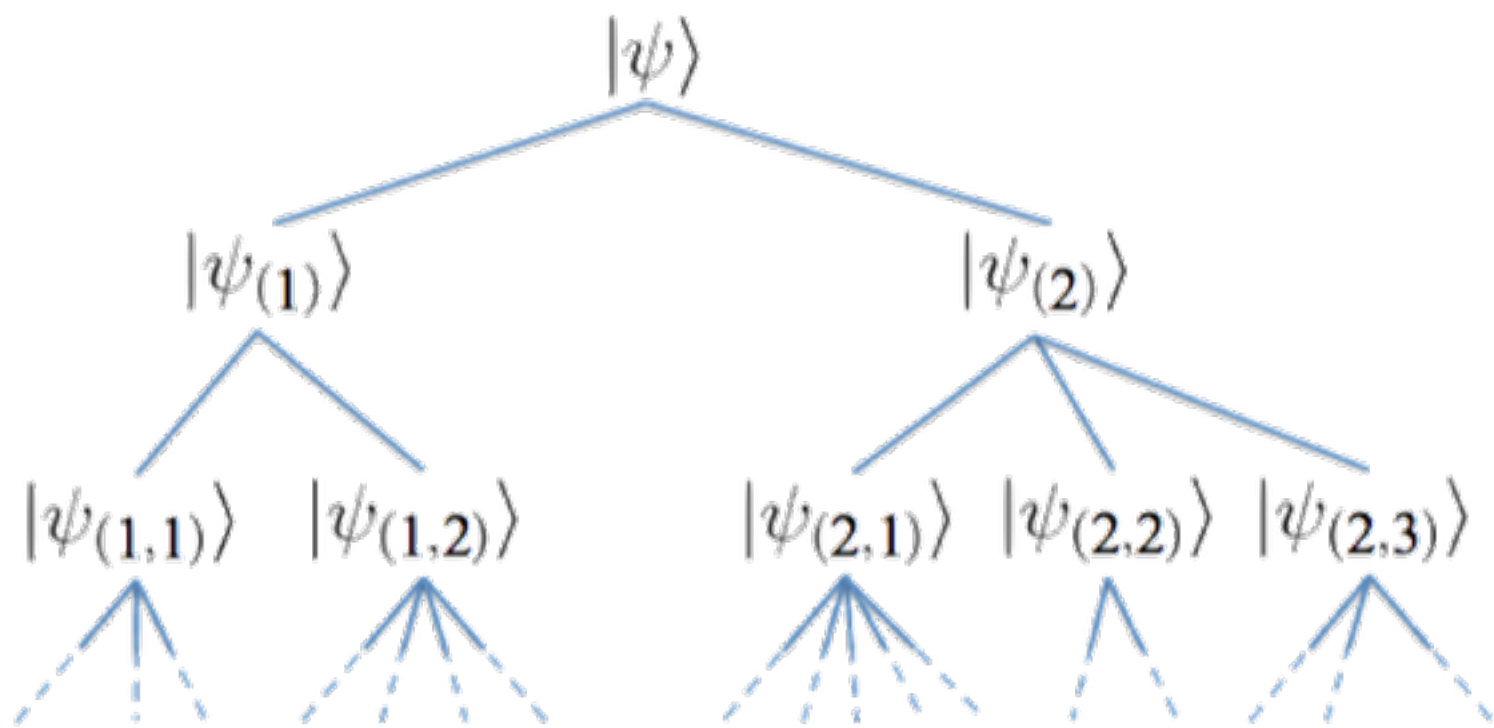
On left side: Clifford-torus is a tetradimensional object of which we are here forcedly seeing a projection. We have developed less than 100 billions of neurons: not enough to perceive events which are happening on an arena whose spatial dimensionality is, as a minimum, 4. What we see in the video on side, is never what really the Clifford-torus is and look like as seen by a tetra dimensional point of view we’ll never have. As a consequence, the details of the branching superpositions of states, corresponding to Measurements and looking like bifurcations, can be finely followed but only mathematically

2. Double-slit with air

On the opposite, a decoherent set of histories is one for which the quantum mechanical interference between individual histories is small enough to guarantee an appropriate set of probability sum rules, what represented by the bell-shaped distribution observed above, on right side. It is the continous measurement of an object by all other objects, in our industrial Environment mainly molecules of that mix of O, N, He, CO2 we name *air*, under the permanent bath of light, the reason why we do not see simultaneous alternative Triggered Events. In other terms, the Environment induces a super selection, separating in two or more subspaces the (Hilbert) space where objects really exist. What above, around one century ago induced what was then the mainstream interpretation of Quantum Mechanics (Copenhagen’s school) to establish a *Wave-Particle Duality* which further experiments, improved technologies and theories, showed a mere illusion.

Since decades it is clear that is Decoherence what lets us perceive in a unique status for what is superposition of states and that, *all* is:

- waves;
- branching superpositions of waves.



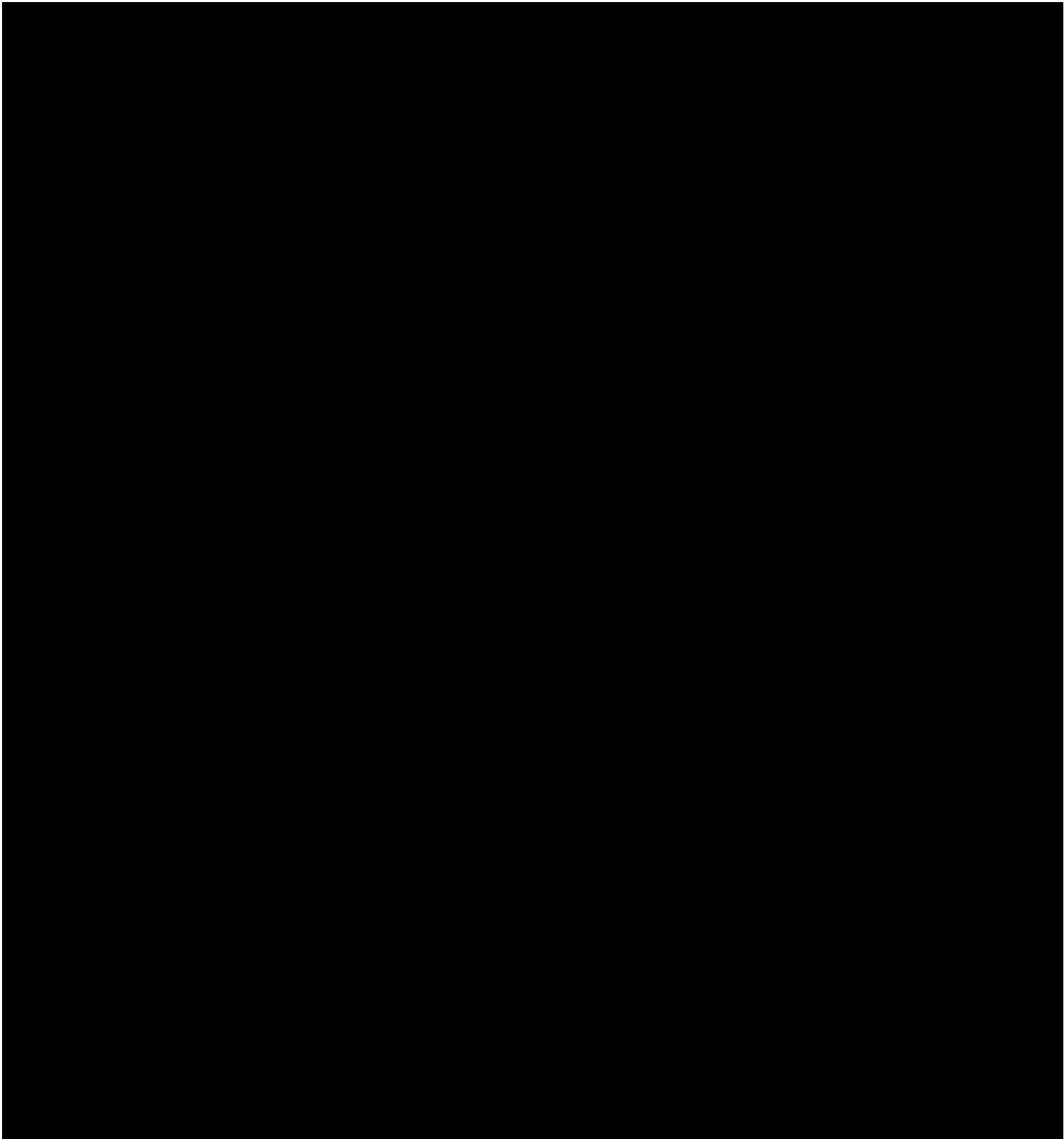
On left side: evolution of the coherent history of the wave function Ψ . In two branches $\Psi_{(1)}$ and $\Psi_{(2)}$, separately evolved in five branches $\Psi_{(1,1)}$, $\Psi_{(1,2)}$, $\Psi_{(2,1)}$, $\Psi_{(2,2)}$ and $\Psi_{(2,3)}$, evolving in further seventeen branches. Such scenario is cited today in the scientific literature very frequently. An amount of technological facts encounters there its only explanation (figure abridged by Zurek, Riedel, Zwolak, 2013)

Decoherence speed

Imagine a physical object as heavy as a Bowling Ball in an Environment in standard conditions of temperature, air pressure and humidity. It is a superposition of a multitude of possible correlations between its elementary components (quarks, gluons, leptons, etc.) *and* all of the others building up what we name Environment. Its even and odd components have equal classical components but opposite quantum interferences. The Laboratoire Kastler Brossel of the French CNRS processed such an object subtracting their Wigner functions, then isolating the interference feature displaying their quantumness. The result is the evolution of this signal over 50 ms, exhibiting a fast decay after only a few milliseconds due to Decoherence, of the original pure interference pattern which represented the physical object.

“Why do we only experience individual sharp superpositions, single bowling balls, rather than multitudes ?”.

Because all others get damped out by decoherence, before we have the time to observe them”



How fast Decoherence happens is known since two decades. In the Table below, showing the Decoherence Rates (or, Localization Rates), expressed in units of $\text{m}^{-2} \text{s}^{-1}$ are represented three cases representative of objects of micro-, meso- and macroscopic scales:

- an electron, not binded to any atom;
- a dust particle, at the limit of unaided eyes visibility;
- a bowling ball.



On left side: magnesium fluoride multicoating anti reflective treatment, well visible by its pink colour in this camera, is a practical example of quantum interference. Here, destructive interference is used to increase the Signal-to-Noise relation of the Information contained in the image

Below: bowling balls decohere in a time extremely short, explaining our sensation of their unique existence in a definite place

We'll be now more precise about how our operative ambient conditions [thermal background temperature $\sim 300 \text{ K}$ ($\sim 27 \text{ }^\circ\text{C}$) in air at a pressure of 1 atmosphere], imply extremely high localization rates for an object of the size of a bowling ball, but fourteen orders of magnitude smaller for an object as small as an electron. The effect of air, or any other surrounding substance, and black-body radiation from the surrounding is strongly temperature dependent

(typically $\propto T^5$), and can hence be reduced by nine orders of magnitude by working at liquid Helium temperatures or, in a smaller extent, taking profit of a Peltier-effect cell. Exactly the strategy followed when looking for maximum performances of Optoelectronics' devices, first of all: the CCD-sensors. Comparing these results with conditions of minimised scattering, like the exposure of these objects to the cold ambient with the only cosmic background radiation, at a temperature of $\sim 3 \text{ K}$ ($\sim -273 \text{ }^\circ\text{C}$), the macroscopic bowling ball decoheres in a time 10^{28} shorter than what we experience.



On left side: the classic or non-classic behaviour of the objects as an effect of Decoherence by the surrounding environment. Tabular values show the Localization Rate,

Decoherence rate Δ in $\text{cm}^{-2}\text{s}^{-1}$ for various objects and scattering processes

Cause of apparent wave function collapse	Free electron	$10\mu\text{m}$ dust	Bowling ball
300K air at 1 atm pressure	10^{31}	10^{37}	10^{45}
300K air in lab vacuum	10^{18}	10^{23}	10^{31}
Sunlight on earth	10^1	10^{20}	10^{28}
300K photons	10^0	10^{19}	10^{27}
Background radioactivity	10^{-4}	10^{15}	10^{23}
Quantum gravity	10^{-25}	10^{10}	10^{22}
GRW effect	10^{-7}	10^9	10^{21}
Cosmic microwave background	10^{-10}	10^6	10^{17}
Solar neutrinos	10^{-15}	10^1	10^{13}

expressed in units of $\text{cm}^{-2}\text{s}^{-1}$, for the center-of-mass of three different objects, in order of decreasing strength. Localization Rate measures how fast interference in between different positions disappears for distances smaller than the wavelength of the scattered objects. Here shown the localization rates for 3 cases: a quark (electron) not binded to any atom, a dust particle and a bowling ball. Our operative ambient conditions are met at a thermal background temperature $\sim 300\text{ K}$ ($\sim 27\text{ C}$) in air at a pressure of 1 atm, implying extremely high localization rates for an object of the size of a bowling ball, but fourteen orders of magnitude smaller for an object as small as an electron (table abridged by Tegmark, 1993)

These studies allowed to answer the main question arising after 1957:

“Why do we only experience individual sharp superpositions, single bowling balls, rather than multitudes ?”.

.....because all of the others get damped out by Decoherence, before we have the time to observe them.

Decoherence limits

Decoherence is a process with the same fundamental limits seen in the start of this page, with respect to the volumes of space causally connected with the Trigger Events, a subject we’ll deepen in the following.

Refer to the figure below, where:

- blue coloured, 3-D volume (encoded in 2-D for graphic rendering) of space hosting the environmental factors E (e.g. air, thermal photons) and the quantum system S;
- red coloured, 3-D volume causally disconnected;
- M, Trigger Event;
- S, quantum system interacting (“measured”) by the Trigger;
- A, macroscopic measurement instrument, e.g. a Trigger photosensor.

The majority of the space is always causally disconnected. We are indicating as a black colour bold inclined line, the worldline of the macroscopic measurement instrument A (the Trigger). Inclined with respect to the Time axe, to manifest the fact that the instrument is over a non inertial platform.

What precedes has an interesting implication: the macroscopic measurement device A (the Trigger, in our case) continues to remain in superposition of statuses, not decohered, for all what is so far to result causally disconnected. Say, all what in the figure below lies in the space and is shown in red colour. The reduced volume that we consider Environment of a Food and Beverage Bottling Line, assures that all triggerings and measurements are always derived by interactions with decohered states. As visible by the figure below, this assumption is a fiction useful to simplify an extremely complex relation. As all fictions, it cannot provide definitive solutions nor improvements on hard-to-tackle technical issues.

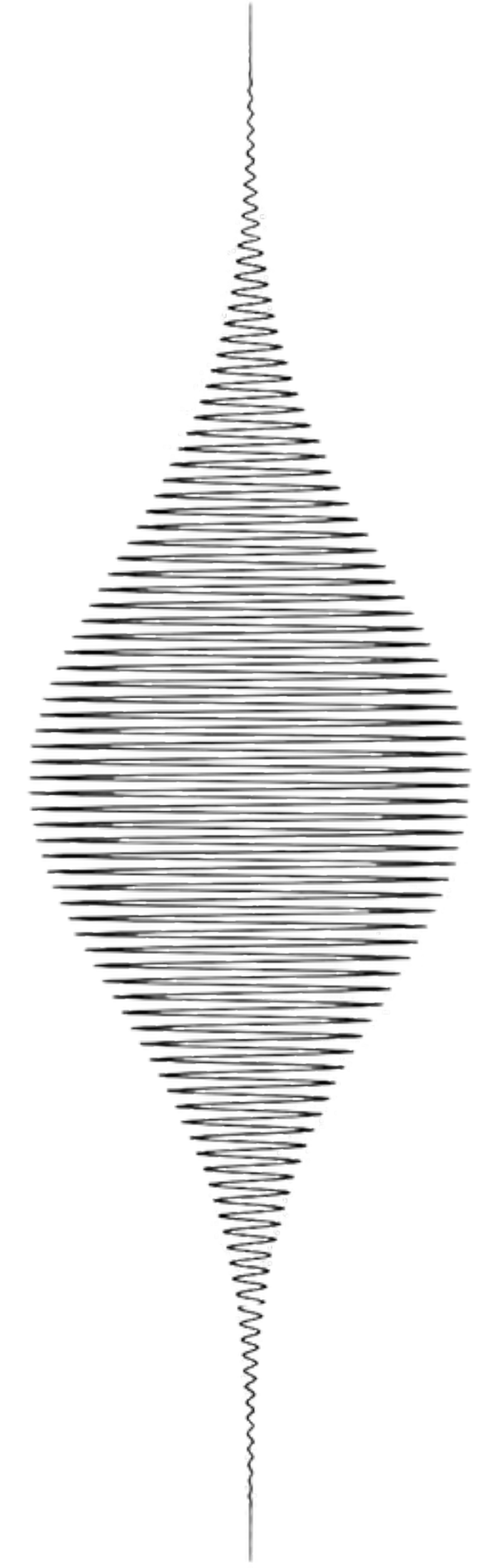
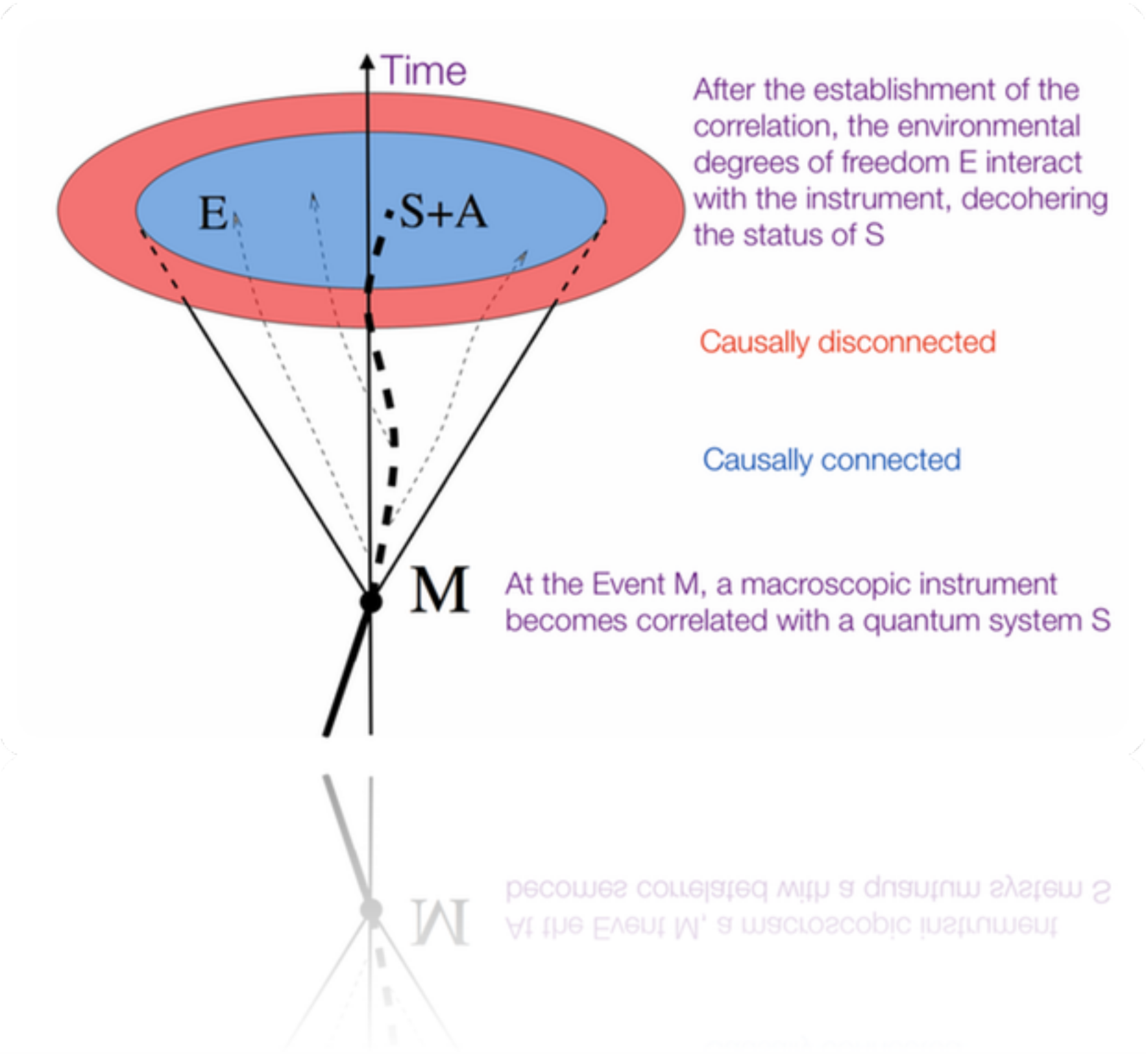
This subject is reminiscent of the Problem Solving method searching for the root cause of a problem centered on the point where the effects are felt. A strategy commonly followed when an evident cause cannot be encountered in the space-time volume we choose to consider the *connected Environment*.

In these cases, we are searching for all of the thinkable cause-effect relations:

- in space volumes progressively increased;
- going backward in time.

The answer of modern Physics to this point is dual, stating that all:

- subsystems are in a superposition of statuses, as seen by all of the other subsystems, causally disconnected because too far;
- what lies into the future lightcone of the measurement Event M is related to M and gives rise to effects S + A conditioned by the Environment E.



▲ All measurement systems, Bottling Controls and Machinery, are themselves superpositions of waves like the photon wave packet depicted above. Particles do not exist at all and the reason we are still naming waves in that way, is mere custom

On left side: the measurement of a physical property by a macroscopic instrument, e.g. by an inspection in a Bottling Control, is subject to

On right side: photons are superpositions of wave packets of something, a fundamental concept (an axiom) we'll name here energy without even to try to explain its nature. The well known diffraction of white light in a spectrum, corresponds to a macroscopic observation of a reality whose arena lies in the microscale. Something we are capable to perceive directly only because effect of the participation of a multitude of photons

additional limits. Only the properties of objects S and of the environment E into the causally connected (blue colour) volume of space, part of the future lightcone of the Event M (the Measurement), shall be decohered. This, means that the macroscopic measurement device A continues to remain in a super position of statuses for all what lies in the causally disconnected - red coloured - space (image adapted by L. Susskind, R. Bousso, 2012)



Electronic Inspectors' nonclassic components

Runt pulses and nonclassic Bottling Controls' components

Following modern views about what really a measurement is ([../Trigger-Physics/index.html](#)), it also becomes possible to understand why they are unavoidable the Runt Triggerings. Triggerings on Runt pulses are not simply *errors* of the system, rather also hint to the reality of what really happens on a smaller scale arena where and when Signals, of extremely brief duration and energy, super impose themselves. Interfering, sometimes contructively building up a spiked signal, some times destructively creating a hole in an other wise constant amplitude. A constant fluctuation around values looking us *constant* only because integrated along extended periods of time. Extended periods of timebecause of sampling rates inadequate to let us go closer to the reality. All technicians involved in Electronic Maintenance know that connecting an oscilloscope to a metal object, then setting a Time base like 1 millisecond, discloses a scenario of jitters and spikes, generically named *noise*. Due to the complexity the subject, in the following we'll illustrate them by a massive use of figures. Its most relevant component induced by the mains power grid, easily recognized by its frequency of 50 Hz or 60 Hz.

On right side: connecting an oscilloscope to a metal object, then setting a Time base like 1 millisecond, discloses a scenario of jitters and spikes. When furtherly zooming also discontinuities may appear (credit Agilent Technologies®, 2013)

Electronic inspectors non classic components



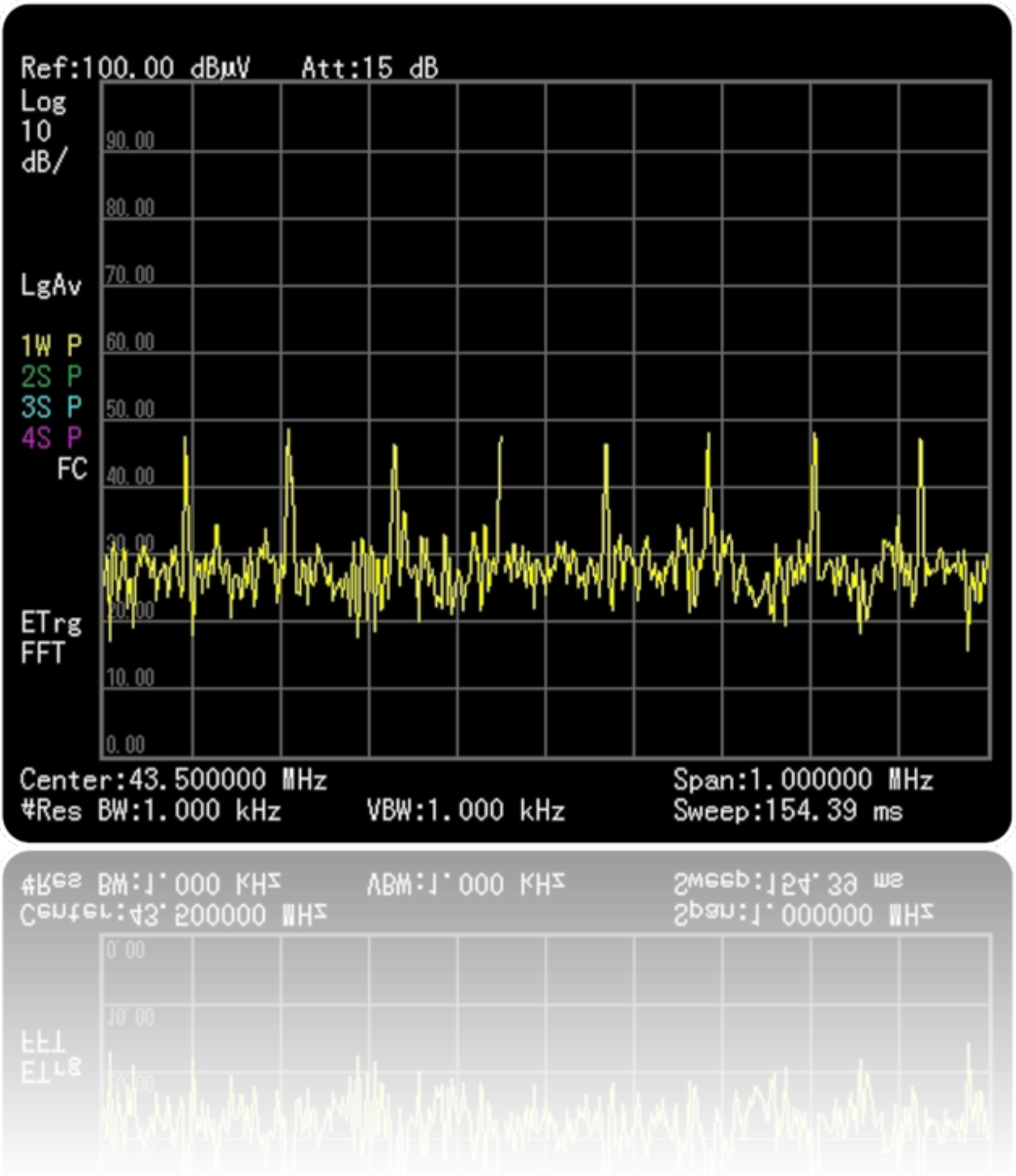
(triggers-as-electronic.pdf)

11 pages, 6.7 MB

(triggers-as-electronic.pdf)

On left side: also consumer cameras use a Trigger. The mechanic push button traditionally opening the shutter front of a film, is replaced by a soft-key triggering a sequence of measures and evaluations, preceding the image acquisition and saving

On right side: non-classic Quantum effects are wherever. Massively active also in this Server. Nonlinear components are > 99.9999 % of the total components. They follow Quantum principles and theorems. Same is true for Bottling Controls



But, accessing a different kind of instrument, one capable to clock also pulses shorter than one attosecond (10^{-18} s), it becomes possible to witness what scientists started to see more than 60 years ago. Then, the arena of apparent *noise* starts to show a distinct pattern: average values, nearly constant along time, tend to disappear, replaced by irregular functions sporting discontinuities. Runt pulses are pulses that don't reach a valid high or low level, meaning they'll reach potentials intermediate between

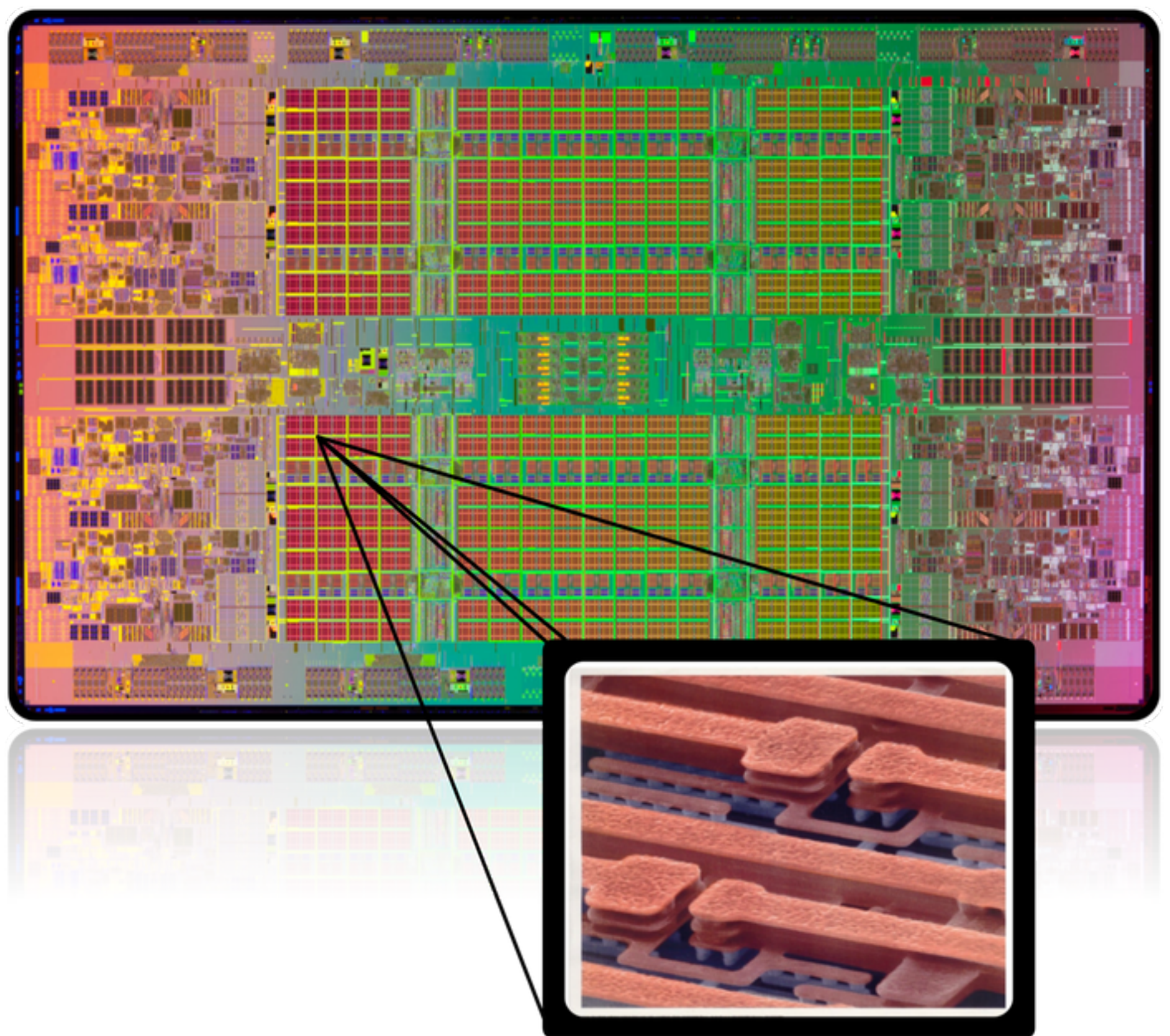
what are considered logic “High“ and “Low“ statuses. They appear for a variety of reasons, and are frequent in the harsh conditions of all of the Food and Beverage Bottling Lines.

On right side: nanometric close-up of the few millimeters over which they lie 3.1 billions of transistors building up the 8-cores Intel® Itanium™ Poulson 9500. Each transistor operates following the Quantum postulates and theorems associated to the Schroedinger equation. Their size is 32 nm (image credit Intel®, 2011)



In the following, listed only seventeen of the multitude of reasons:

1. dust or dirt on the surfaces of photoelectric switches;
2. uncertain switching of inductive sensors,
3. humidity on the surfaces of photoelectric switches;
4. induction of transient potentials in the signal line, due to insufficient or missing radio frequency shielding of the trigger sensor cable;
5. fluctuations of the mass (common) potential of the sensor and/or of the IO circuit in the Electronic Inspector, due to defective insulation of the windings of motors;
6. intrinsic fluctuations of the potential of the sensor's inner electronics;
7. intrinsic fluctuations of the potential of the Electronic Inspector IO electronics processing a trigger sensor signal;
8. incorrect orientation of the light beam emitted by the Projector, in the trigger sensors based on Projector and Receiver;
9. excessive distance between Projector and Receive, in the trigger sensors based on Projector and Receiver;
10. excessive distance from the sensor of the metal body used as a phase reference in the



- inductive trigger sensors;
- 11. incorrect orientation of the sensor of the metal body used as a phase reference in the inductive trigger sensors;
- 12. optical effects (diffraction and/or reflection and/or refraction) in the glass of the neck of the bottles or the paint over the external surface of the cans, used by a photoelectric barrier as a source for its out coming trigger signal;
- 13. reduced ferromagnetism of the metal body used as a phase reference in the inductive trigger sensors;
- 14. excessive speed of the metal body used as a phase reference in the inductive trigger sensors;
- 15. excessive speed of the bottles or cans used by a photoelectric barrier as a source for its out coming trigger signal;
- 16. temporary mechanical vibrations of the terminals where trigger sensor conductors are connected, implying false contacts of extremely brief duration;
- 17. oxidation of the terminals where trigger sensor conductors are connected, implying false contacts of extremely brief duration.
- 18.



Above: Intel® Broadwell™ CPU has several billions of transistors sized 14 nm. It'll be introduced in the end of 2014 (credit Intel®, 2013)

The IO digital inputs of the Electronic Inspectors can be equipped with separate circuits counting, for each one channel, all of those Trigger pulses that, in the reality, did not reach a valid “High" or "Low" level.

This is possible by:

- 1. setting two threshold levels, rather than one;
- 2. looking for signals that only cross one of them.

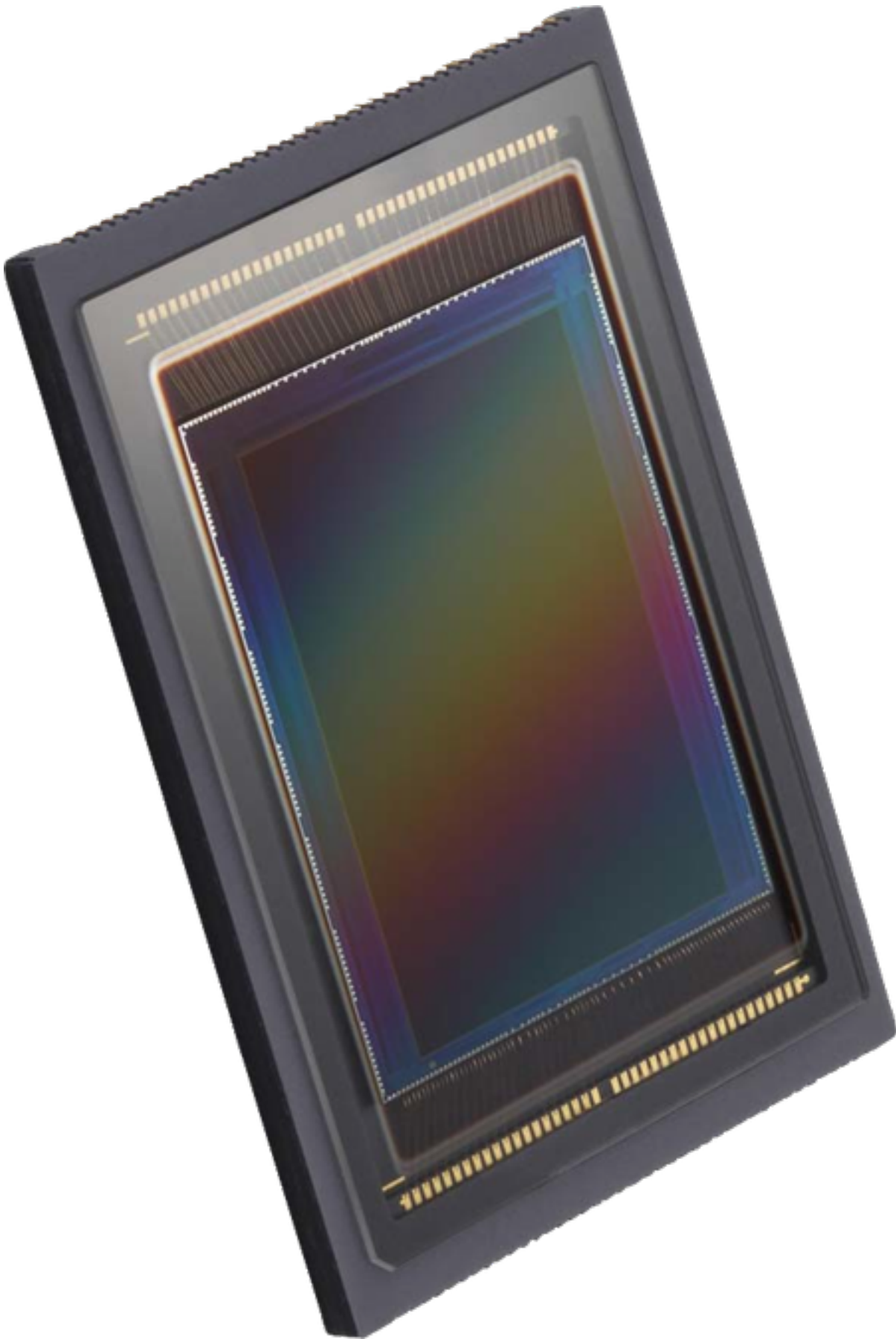
Knowing what IO line, what Trigger, is introducing runt signals and setting a limit for their frequency, a limit related to the actual frequency of processed containers-per-hour, it becomes possible to make available to the Bottling Plant Staff extremely useful auto-diagnostics. Diagnostics pre-emptive with respect to permanent fault statuses otherwise later affecting the entire Electronic Inspector and, from there, the entire Bottling Line.

Today > 99.9999 % of the Electronic Inspectors' components are nonclassic

All, whatever its scale of dimension and duration, behave this way and the Bottling Controls are not an exception. Electronic Inspectors always include macroscopic devices, devices whose size, mass and duration is not very different than Our own, whose operation is nonclassic and nonlinear, like:

- transistors, massively present into all Integrated Circuits welded over printed circuit boards visible in several figures in these web site;
- rectifier diodes, based on semiconductor junctions;
- CCD-cameras, based on bidimensional arrays of semiconductors;
- CMOS-cameras, based on bidimensional arrays of semiconductors;
- X-rays solid state detectors, based on arrays of phototransistors;

Below: 120 megapixels vision sensor



- Trigger photosensors, using LASER sources and detectors based on semiconductors (like the one visible in the video in the initial part of this page).

If we divide all of the electronic components into an Electronic Inspector in two categories:

- **linear**, resistors + capacitors + inductors + connectors + cables;
- **non-linear**, transistors in and out of Integrated Circuits + rectifiers;

and relate them, we'll discover that **> 99.9999 % of the electronic components which let the Electronic Inspector function are today operating following nonclassic Quantum principles.**

And all of the camera-equipped models of Empty Bottle Inspectors and Full Bottle Inspectors include any optical components, like:

- Beam Splitters (see figure above);
- Polariser Filters (see figure left-side down);
- Fresnel prisms;
- ¼ wave delay plates;

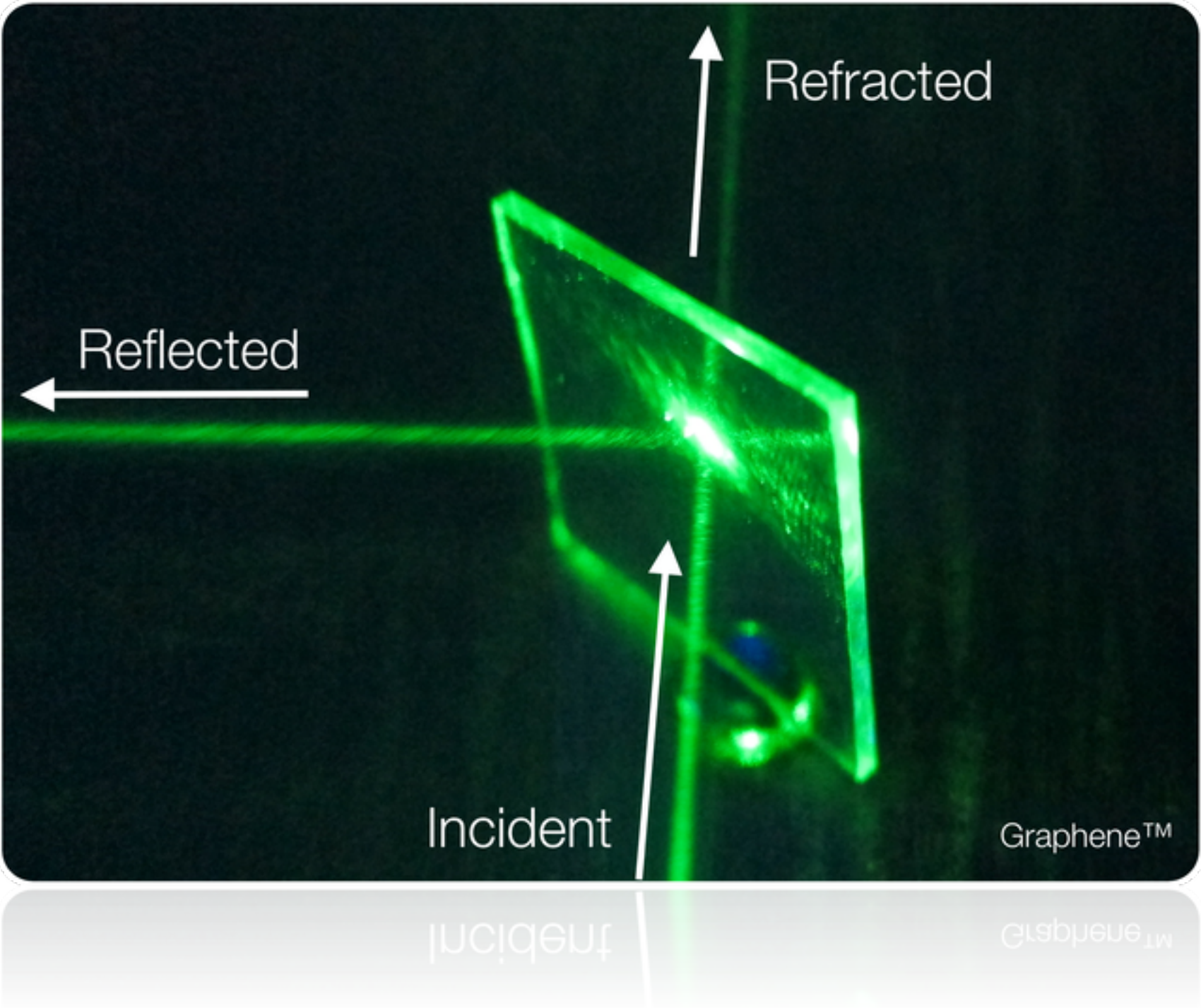
cooperating with the nonclassic devices listed above to accomplish the measurement process named inspection.

The Table down shows some of the many different ways in which these components participate to the measurement process, for selected types of Electronic Inspectors commonly used into Beverage Bottling Lines:

Inspector	Inspection	Detected	Optic components
Full Bottle	Finish	Metal seal defects in aseptic filled beverage	Fresnel prism
Full Bottle	Optical closure	PET cap defects: too high, inclined, etc.	Polariser
Empty Bottle	Base	Opaque foreign objects	Polarisers, Beam Splitter
Empty Bottle	Base	Semi-transparent foreign objects, plastics	Polarisers, ¼ wave plate, Beam Splitter
Empty Bottle	External Sidewall	Opaque foreign objects	Polarisers
Empty Bottle	External Sidewall	Semi-transparent foreign objects, plastics	Polarisers, ¼ wave plate, Beam Splitter
Empty Bottle	Finish	Broken finish	Fresnel prism
Empty Bottle	Infrared	Hydrocarbons	Polarisers, Beam Splitter
Empty Bottle	Inner Sidewall	Opaque or semi-transparent foreign objects	Polarisers, Beam Splitter
Full Crate	Foreign objects	Semi-transp. plastic foils in returned crates	Polarisers, ¼ wave delay plate

Above: peculiar optical components commonly adopted in Food and Beverage Bottling Controls, directly participating to the measurement process enacted in the last by mean of non-classic devices, based on semiconductors. A visit to a Quantum Optics Laboratory confirm a near congruence of Optoelectronics resources

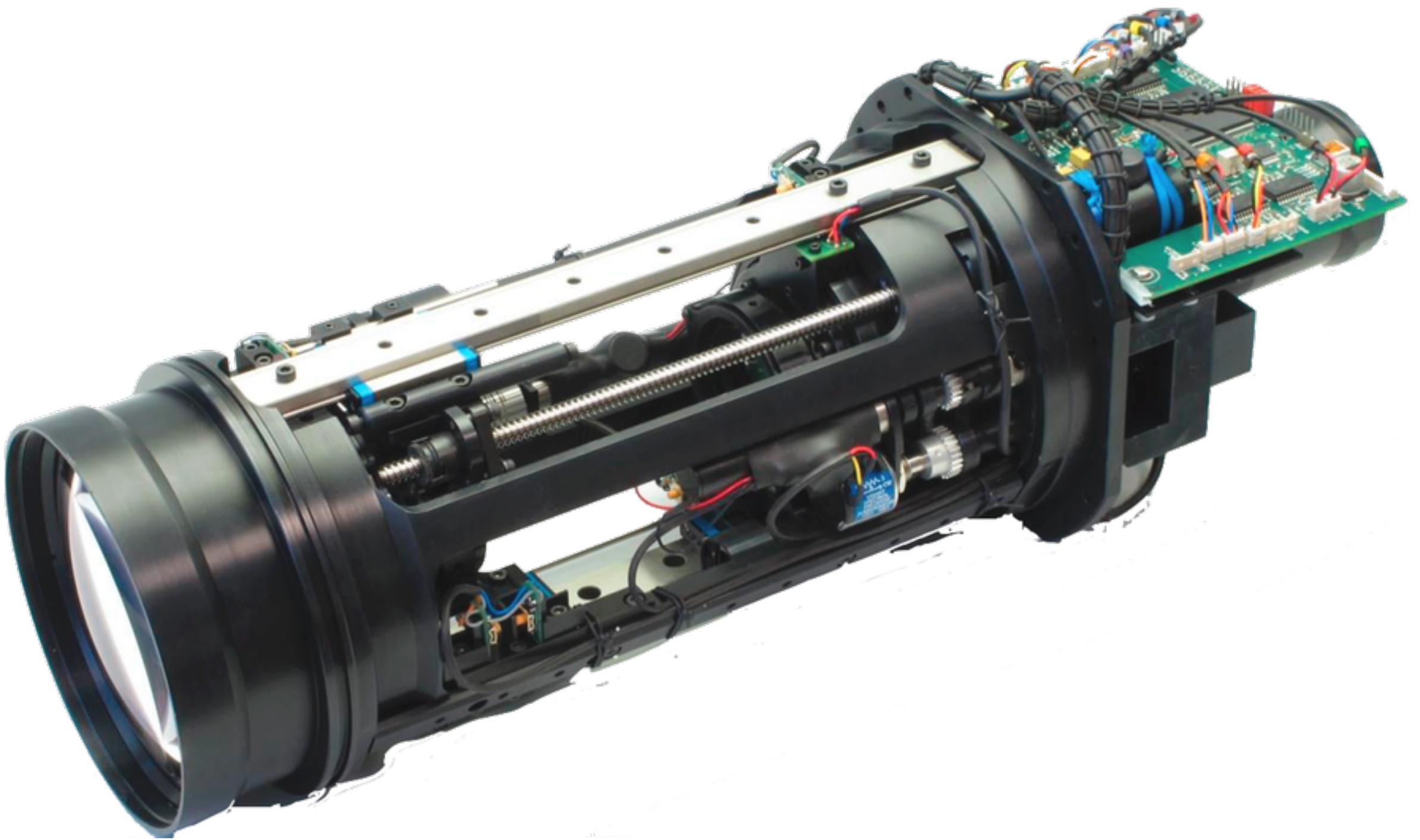
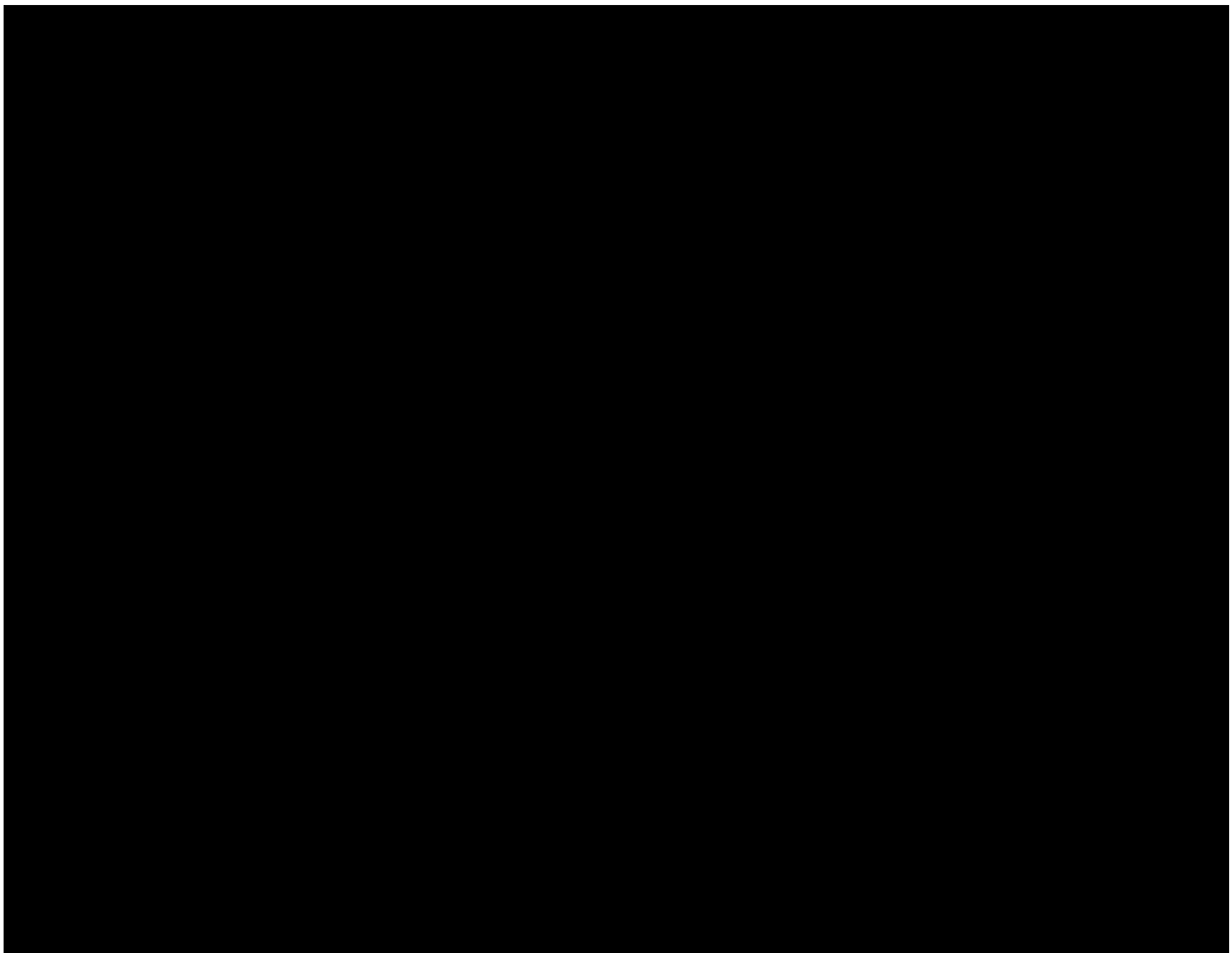
On right side: Beam Splitter. LASER photons, incident, refracted and reflected in different directions by a beam splitter are always part of the experiments of Quantum Optics. And also in all Empty Bottle Inspectors and many Full Bottle Inspectors equipped with cameras. In the example, a meta coated mirror model where the metallic coating is made thin enough to obtain partial reflectance. It is important to understand that all glass panes (windows included) act as Beam Splitters (abridged by Zaereth, licensed under Wikimedia Commons)



On left side: the screw in the inner front of this multiplet of lenses allows the introduction of a glass circular Polarizer filter, like the one in the figures down. The coloured surface visible in the front lens on left side, is an indicator of anti-reflex treatment



Above and below: in the Empty Bottle Inspectors, glass Polarizer Filters like the one visible in the animation below, are frequently set in front of the zoom lenses to increase Signal-to-Noise ratio. This, allowing detection of defects otherwise invisible. Polarization is a popular synonymous for a non-classic property of each one photon, named spin



Above: opening the optic of a modern industrial vision system reveals that nonlinear nonclassic solid-state electronics replaced the classic optomechanical zoom manual adjustment

LED Projector-Receiver Triggers allowed reduction of the *false trigger signals*. Later LASER light Triggers continued to ameliorate the triggering function, reducing still more the *false Triggers*, but is knowingly impossible to encounter a Technology capable to zero them all. We hint to the fact that Trigger signals in amounts inferior or superior, however different than the number of Containers which interacted with the Triggers is a:

- negative feature of all Electronic Inspectors, e.g. creating false rejects or undue actions of the rejectors which may provoke jams and stops;
- behaviour explicitly expected by Physics for systems of this kind.

It could be imagined that such a trend toward quantum-based components shall hit an upper ceiling: that maybe in a few years we'd be spectators of a massive re-entry of linear components in Optoelectronics. As an example, consider the electromechanical hard disk drive (HDD) in the figure on left side, still equipping the



Above: CMOS vision sensor industrial camera



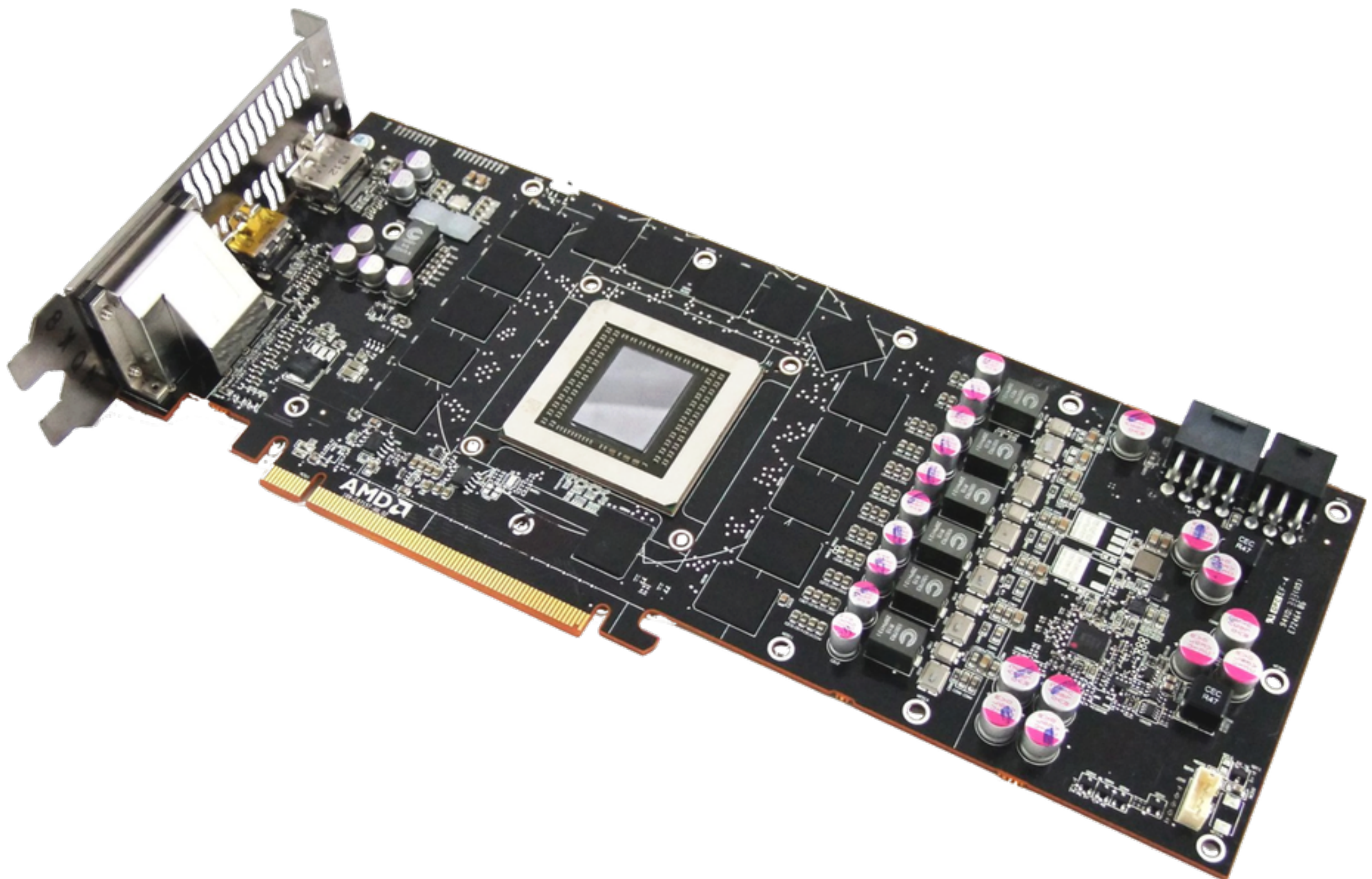
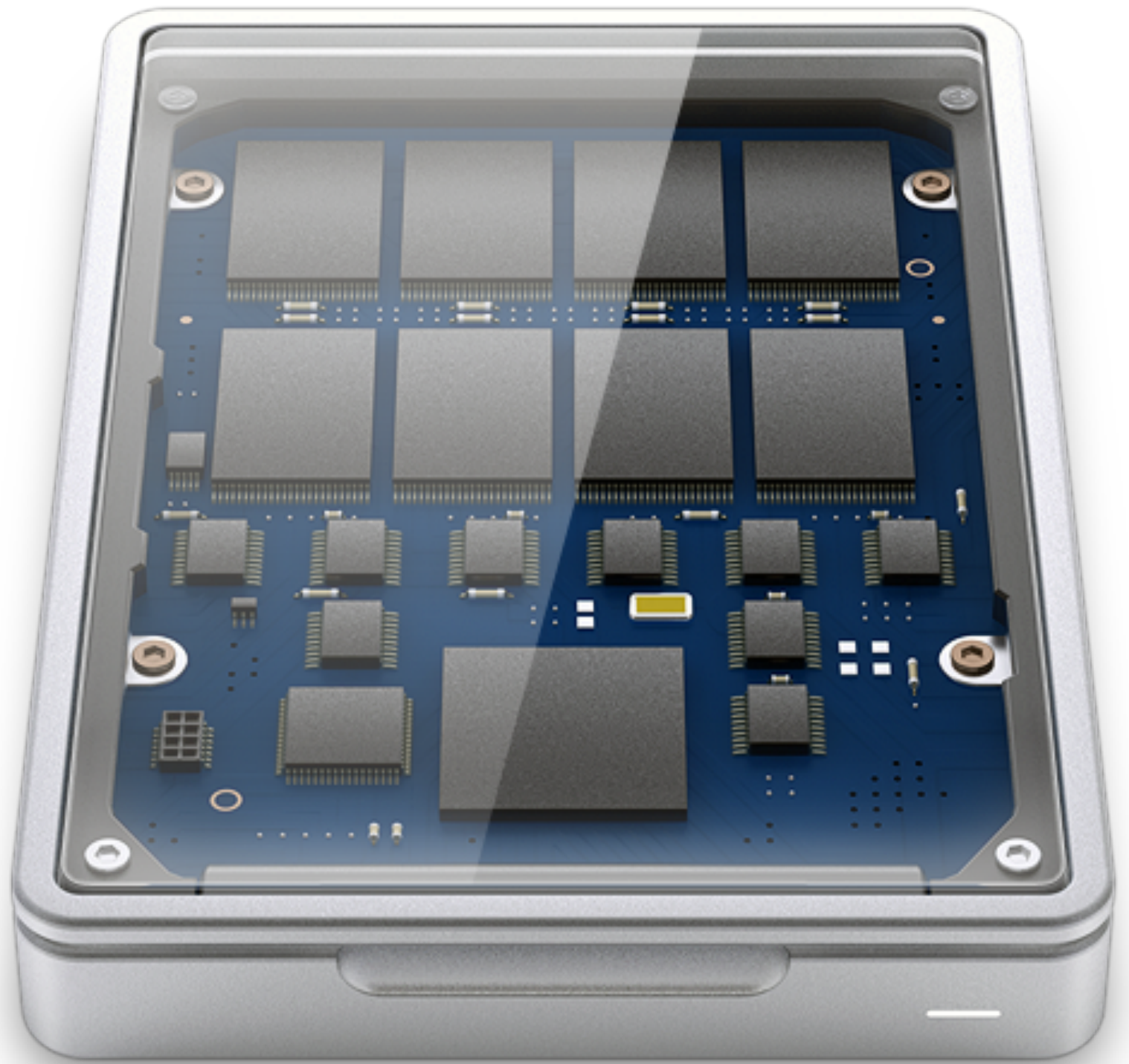
On left side: mechanical disk drives (HDD) are being replaced in the Electronic Inspectors by SSD or FlashPROM solid state devices

Bottling Controls. But, since a few years, there are also Vendors proposing to Bottlers as a retrofit the replacement of these devices with nonlinear semiconductors-based FlashPROMs. Mechanic HDDs' Medium Time Between Faults is short and approximately < 2 years and this really is the excellent reason for the change. In the meantime, Vendors are migrating the technology of the mass memory of the Bottling Controls toward what visible down, Solid StateDrives (SSDs), based on transistors.

Below: a solid state drive (SSD)

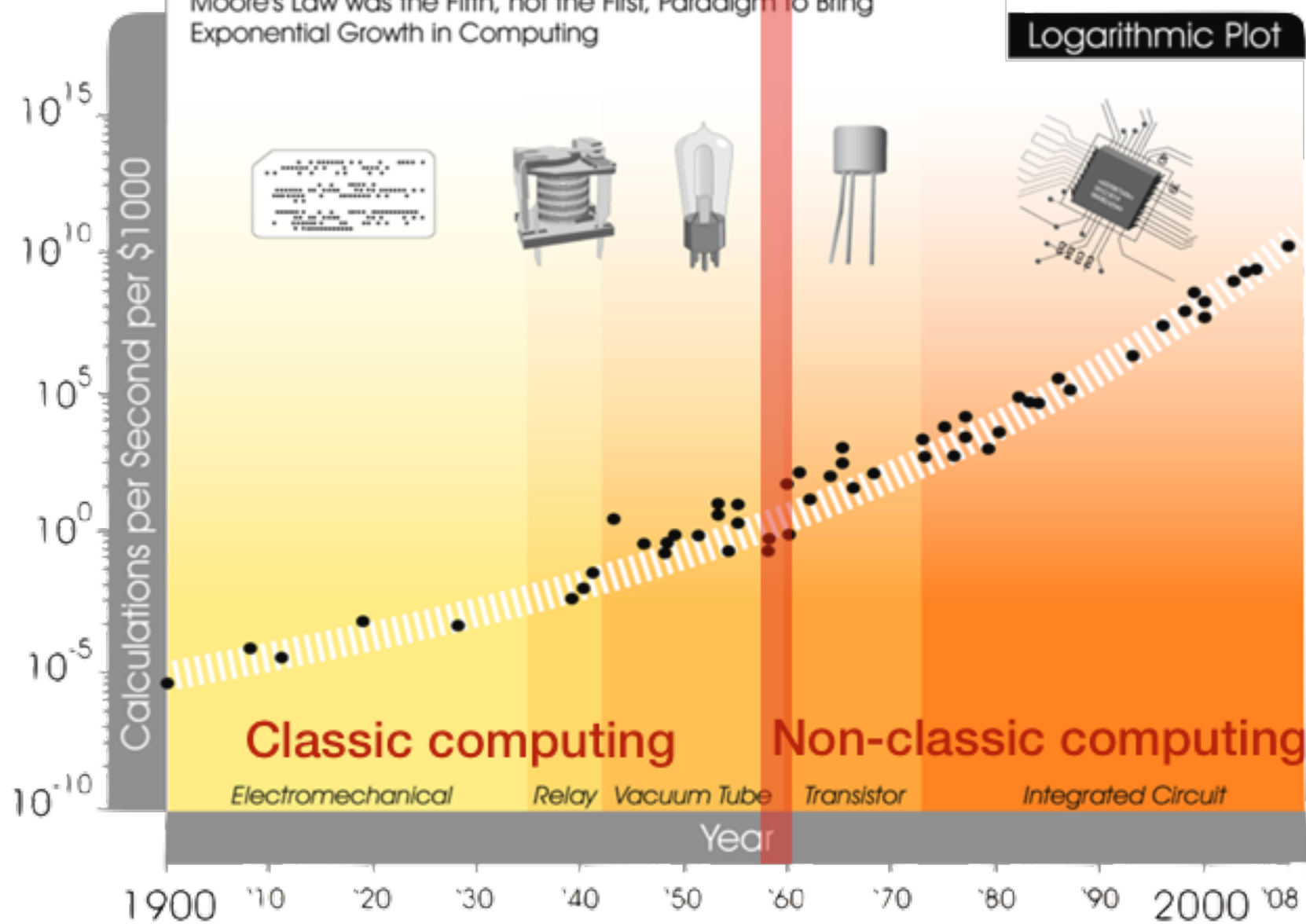
One more time, less space for mechanic or electro-mechanic components and increased presence of solid state non-linear components obeying Quantum rules, rather than laws of classical Mechanics or Electrotechnics. The, the most probable scenario we'll see next in the medium term, is thinkably hinted by the figure down. Knowingly, Graphic Processing Units (GPUs) are an important component of today Image Processing and Machine Vision industrial applications. Shown one of the most powerful consumer-level GPUs of the World: its **6.3 billions of transistors** are confirming we recently entered in a quite different Industrial environment, one destined to be dominated by quantum effects by mean of applications which have only started to be figured. Refer to the chart in the figure in the bottom, right side, showing the growth of computational power from 1900 til 2010.

After nonlinear components introduction into computers, computational power increased ~1 million of billions of times. Nonlinear components diffusion into Bottling Controls is part of a generalised technological trend.



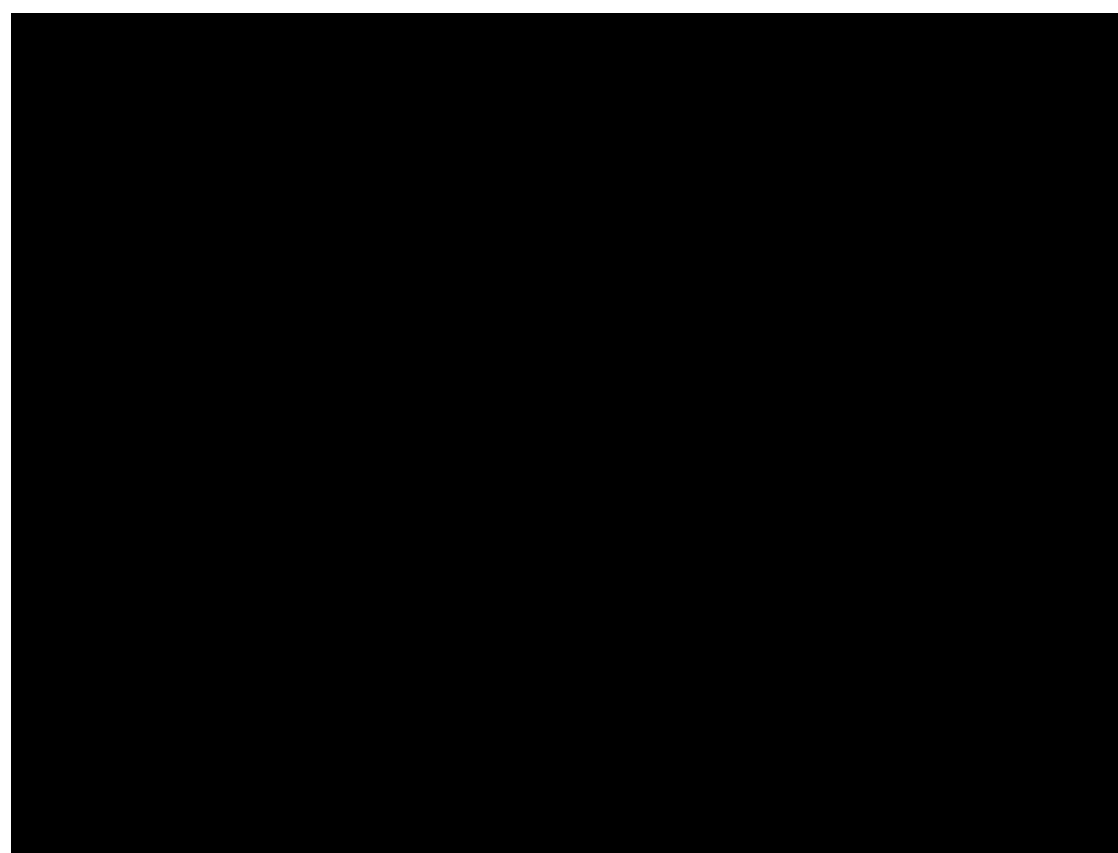
Exponential Growth of Computing for 110 Years

Moore's Law was the Fifth, not the First, Paradigm to Bring Exponential Growth in Computing

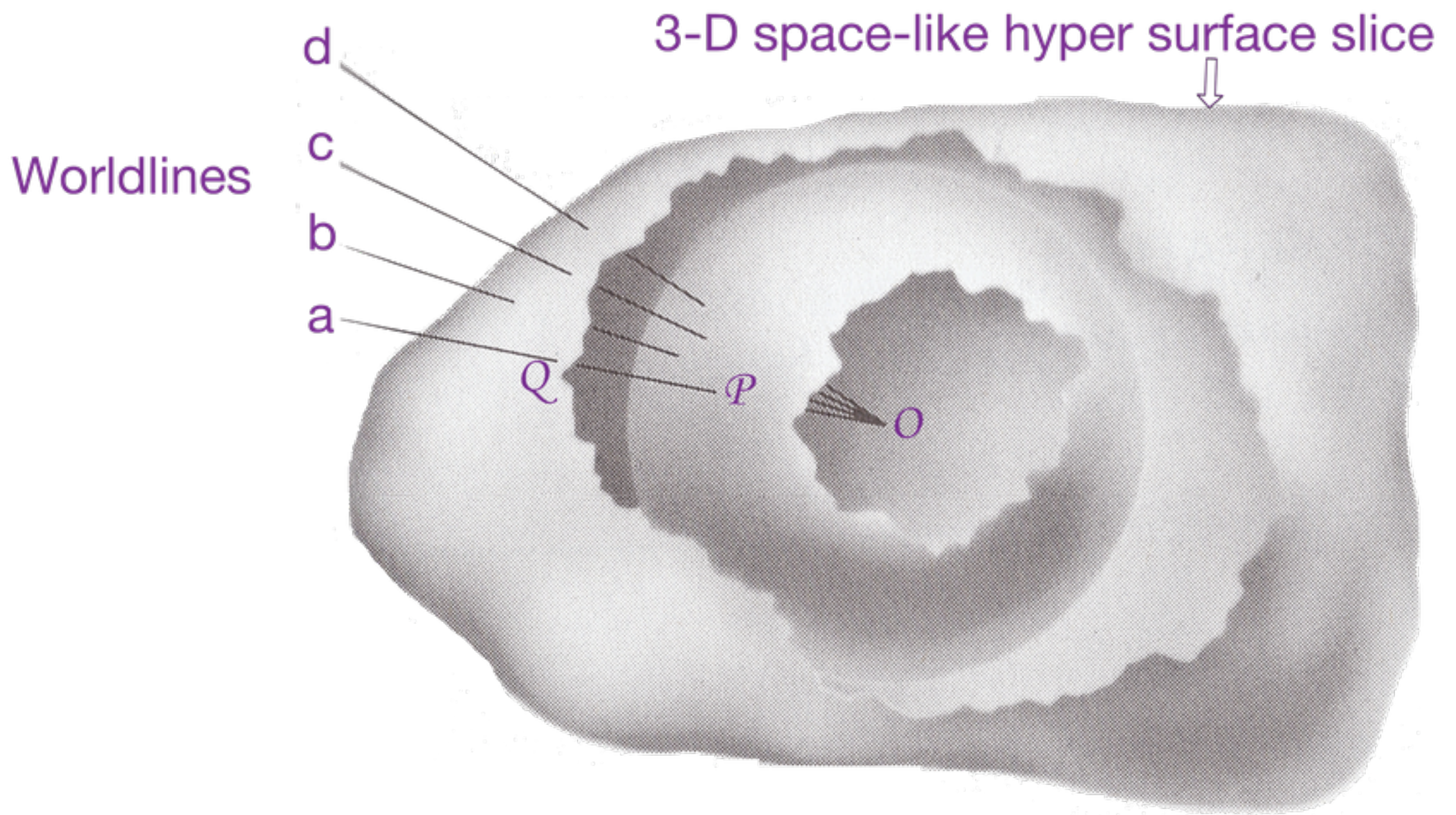


Above: a GPU-card carrying with more than 6.3 billions of transistors with 350 Gflops (billions of floating point operations per second) of processing power

On right side: growth of the computational power after the introduction of transistors, non-classic devices based on quantum principles: ~1 million of billions of times (1958 - 2010)



Events' causal connection



▲ The worldlines of whatever, including all Triggers', measurement instruments', electronic inspectors' and Observers' components, were joint in an extremely small volume when the initial condition acted. Showed four worldlines a, b, c, d originated by the same Event O in the Past, in the classic perspective: four distinct histories. Also technological and analytical applications are part of slices: all of those existing between two Events, e.g. P and Q . Each slice or leaf, is 3-dimensional. Time indicates the location of a chosen 3-dimensional space, an hypersurface in the infinitely wider 4-dimensional space (image abridged by J. A. Wheeler, K. Thorne, C. W. Misner, 1973)

Introduction

Events' causal connection is an extremely delicate subject. Its direct beneficial technological applications in the scientific research as well as the mainly technological Problem Solving and Root Cause Analysis being known examples.

A point of view dated more than one century ago about *causal connection* or *causal relation*, hints to the validity of two *conjectures which were elevated to the rank of principles* yet thousands of years ago:

1. time-ordering of the Events;
2. someone or something *here* acts over someone or something *there*.

These ideas, however ancient they may be, are also the base for a plethora of non-scientific applications, easily recognized because of their capability to show the (apparent) *veridicity* of all and of its opposite.

In the following, we'll examine two different points of view:

- classic, dated 1907, due to the mathematician Hermann Minkowski;
- modern, dated 2000, mainly due to physicist Rafael Bousso.

The definitions of Events (Trigger Events included) and of the derived concept of *causal relation between Events* are part of the investigational fields of Theoretical Physics, Quantum Physics and Relativity. Why ? Because the majority of the (cosmological) evidences hint to a common origin. One characterised by extremely high values for energy density (then, high temperature) and geometrical curvature for the greater Environment where all, measurement instruments and Machinery included, operates. Several wordlines are a System and, with reference to the figure above, it is frequently over looked the fact that all worldlines were joint in a single dot, back in the Event *O*, origin of Time ($t = 0$). This classic point of view, mainly derived by the ideas of Einstein, Minkowski, Lemaitre and Gamow, one time backed by Hubble and Eddington's discoveries, started to hold as a paradigm. And it still holds today, at least in part. To reduce all this to mere *theory* in opposition to *facts* is not possible, so many are the direct applications in our life and Machinery. As an example, all smartphones' GPS location devices integrate routines with formulas of General Relativity to be so precise as they are, evidencing the correctness of the Theory.

We may be interested to evaluate how many 3-dimensional surfaces (or leaves, or sheets) contains the 4-dimensional solid above.

The answer is the sum of:

$$\infty^3 \text{ points;}$$

and, in a coordinate system that makes the metric diagonal:

$$3 \text{ diagonal components of the metric specifiable per space point;}$$

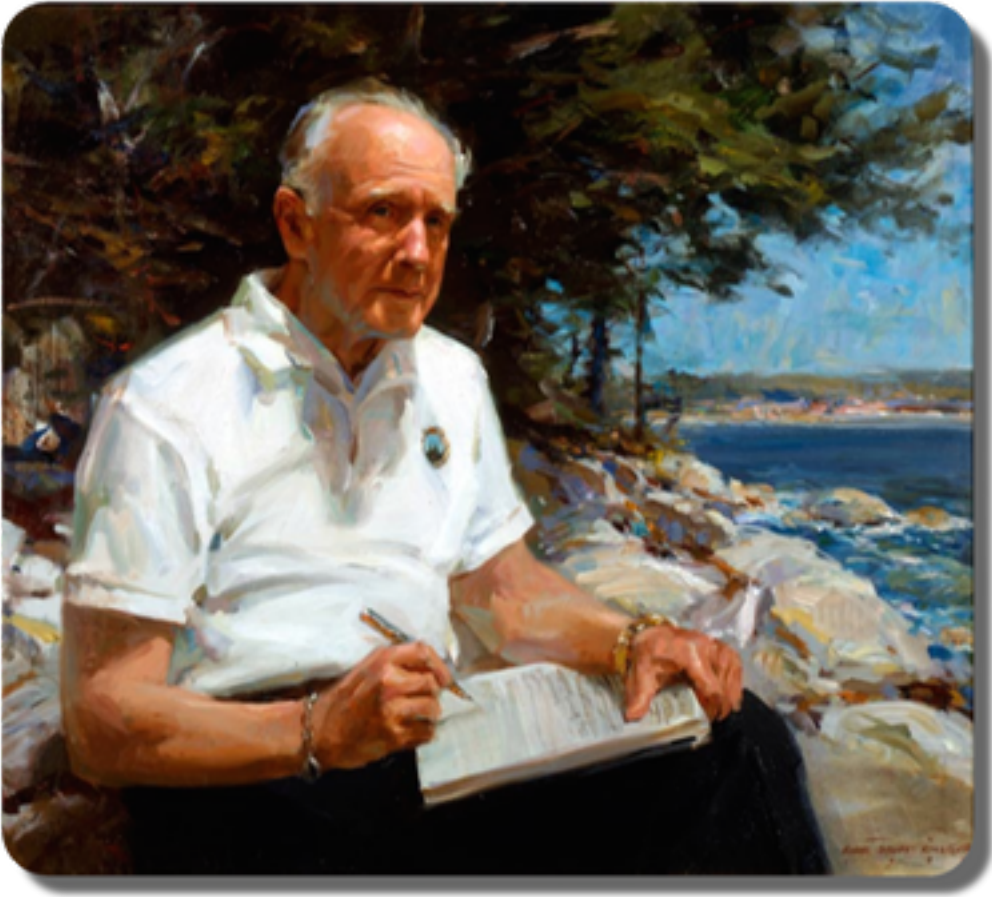
say:

$$\infty^3 \text{ choices of the metric per space point;}$$

therefore, a total amount of *possible* 3-dimensional leaves equal to:

$$(\infty^3)^{\infty^3}$$

Amount later heavily reduced by the added dynamical condition of *constructive interference*, but however a huge amount. These numbers are not shown as a sterile exercise of infinitesimal calculus, rather to enforce that since at least one century Nature answers to the continued questions by the humanity inviting us to replace infinities with *great numbers*. Numbers so big to be easily confused with infinities.



▲ **John Archibald Wheeler,**
student of Niels Bohr before, and
later teacher or mentor of Charles
Misner, Richard Feynman and Hugh
Everett III (image abridged by
Aldebaran Group for Astrophysics)

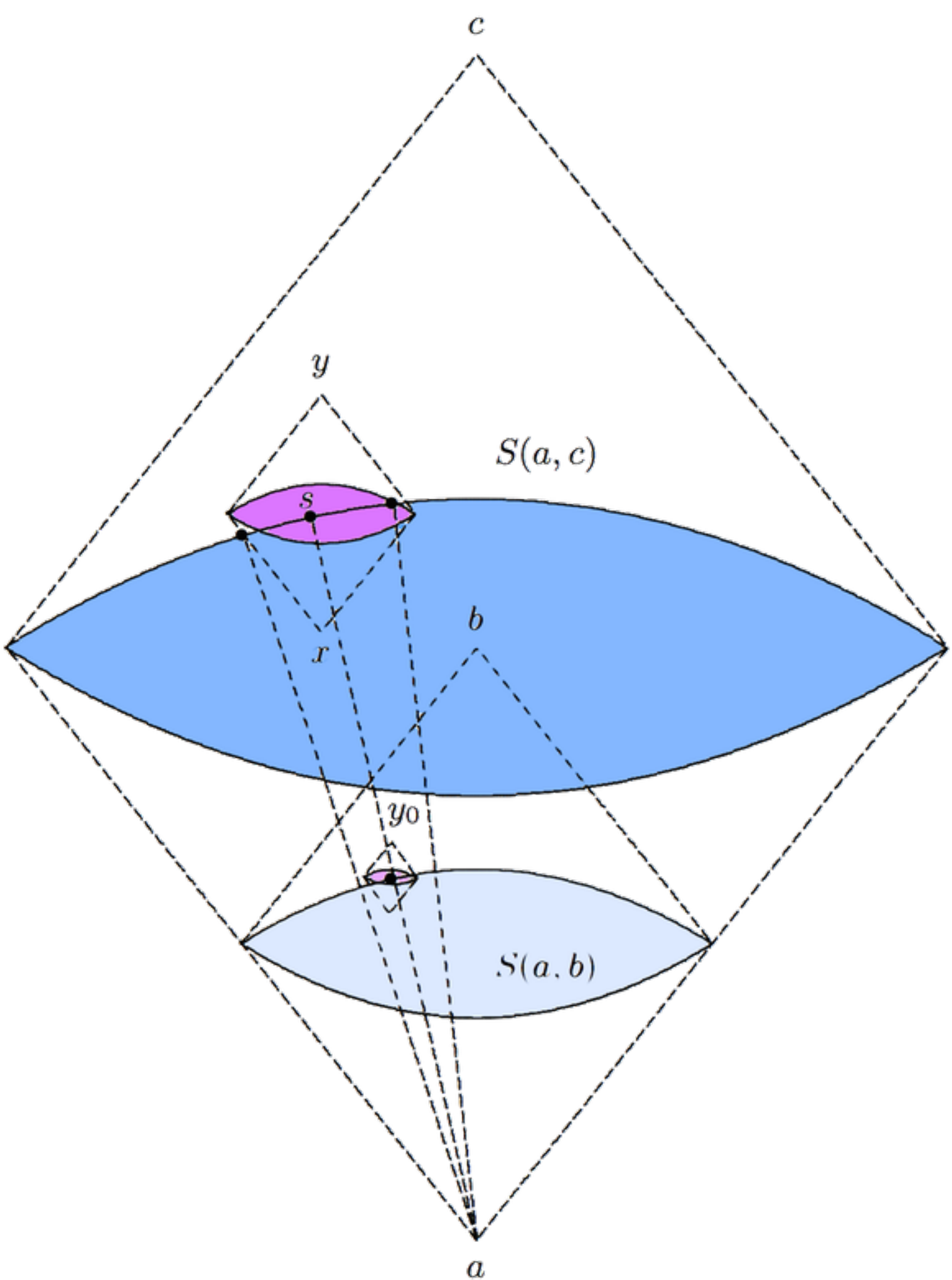
Relevance of the history of the Events

Events strictly or slightly related

In the following we'll introduce Readers to the *relevance of the history of the Events*. The long and, at first sight time-ordered chaining of Events which are considered causes of the Events in the present time. a relatively complex sequence of bicones illustrating why in General Relativity the spatial dots all around a single Event, are related to the Event. The figure below shows a situation constantly present in the reality lived by us and our measurement devices. Here on the base of Minkowski geometry of 1907 an entire spatial volume lying out of the light cone should be causally disconnected by the Event a in its Past. In the reality, it shall result still related, however slightly.

- We start observing the time-ordered sequences where:
- the Event a lies in the Past of the Events b and c ;
 - the Event a lies in the Past of the Events y_0 , x , s and y ;
 - $S(a, b)$ is the hypersurface separating the Future of a by the Past of b ;
 - $S(a, c)$ is the hypersurface separating the Future of a by the Past of c .

The Event s in the Future of the Event x , visibly lies on the external boundary of the Future of the Event a , part of the same hypersurface of constant Time of the Event b . Due to this reason the pink coloured hypersurface centered on the Event s results partitioned. The inner portion hosting a 3-dimensional space-like volume causally related to the Event a much more strictly than the portion lying out of the hypersurface $S(a, c)$ external boundary.



Right side: a relatively complex sequence of bicones illustrating why in General Relativity the spatial dots all around a single Event, are related to the Event. The image shows a special case: here on the base of Minkowski geometry of 1908 an entire spatial volume lying out of the light cone should be causally disconnected by the Event a in its Past. In the reality, it shall result still partially related. Also: the Event a lies in the Past of the Events b and c . a also lies in the Past of the Events y_0 , x , s and y . $S(a, b)$ is the hypersurface separating the Future of a by the Past of b . $S(a, c)$ is the hypersurface separating the Future of a by the Past of c . Visibly, the Event s in the Future of the Event x , lies on the external boundary of the Future of the Event a , part of the same hypersurface of constant Time of the of the Event b . Because of this reason, the pink coloured hyper surface centered on the Event s results partitioned. The inner portion hosting a 3-dimensional space-like volume *causally related* to the Event a much more strictly than the portion out of the hyper surface $S(a, c)$ external boundary (diagram abridged by H.-J. Borchers, R. N. Sen, 2006)

We'll start to list, as seen by the point of view until 2000 considered standard, what is and what is not possible in terms of *Events' causal connection*.

No interaction, gravitational nor electromagnetic, is possible with particles lying in the space out of the bicones: all what lies in that space is causally disconnected with respect to the object placed at the Triggered Event. In this classic approximation, **only what lies in the Past light cone is causally connected with what lies in the Event position**. The Future light cone traces the paths of light rays emitted in every possible direction from the *Event* at the origin, and the Past light cone indicates the paths of light rays arriving at the *Event's* location at the Present moment. In this classic view, the Event has a purely geometric meaning: a dot of space-time. It is not necessarily the place where also happens an interaction.

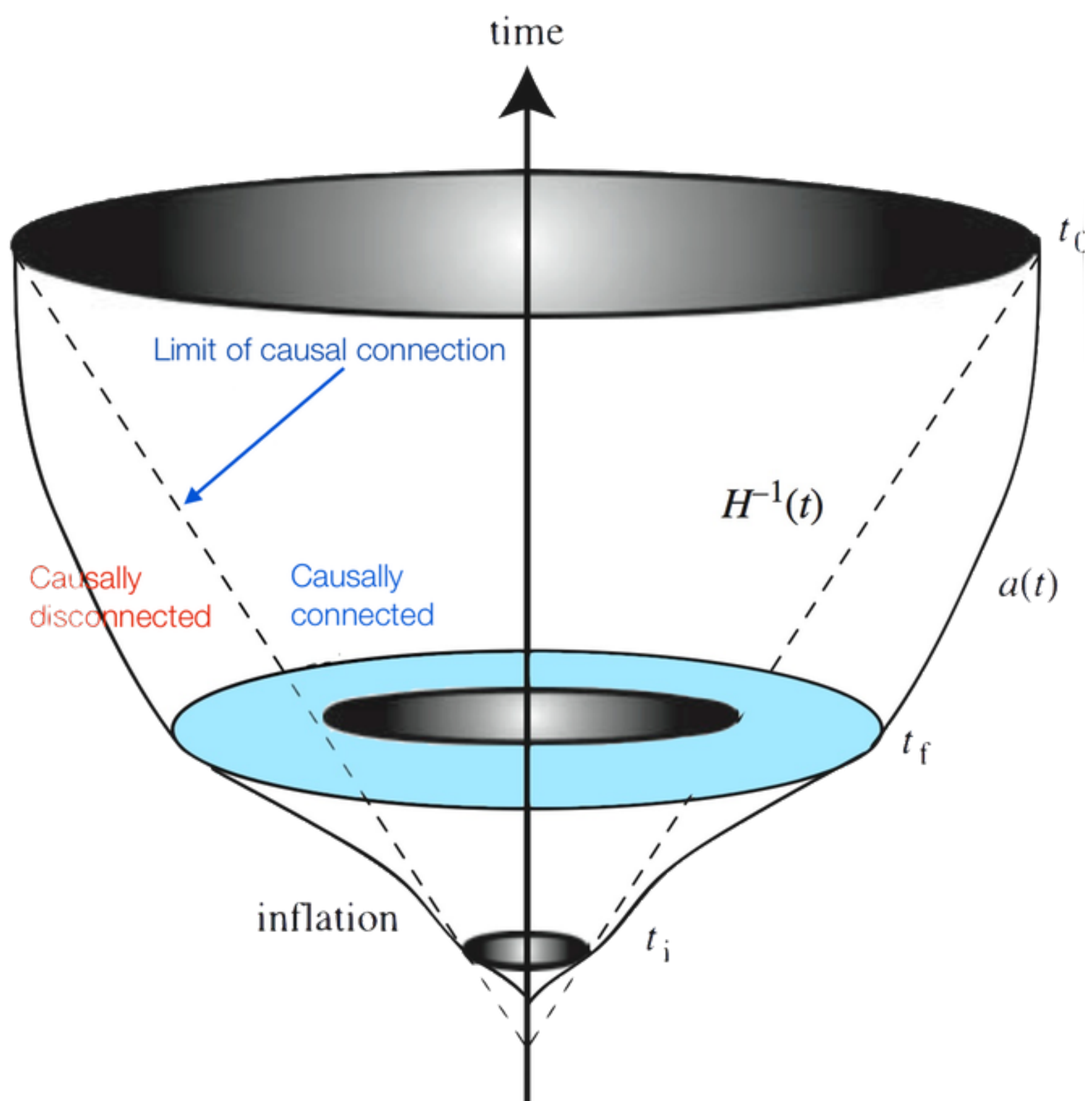
The rules about Events considered valid by Special Relativity, between 1905 and 1915, were:

- light beams emitted from the Event location travel exclusively along the Future light cone. (On the opposite, as we'll see later with more details, in the modern Quantum Physics view, trajectories do not exist and **particles are emitted in both directions, Future and Past**);
- arriving at the *Event's* location at the Present, all fall within the Past light cone;
- launched from the *Event's* location, all travel on trajectories bounded by the Future light cone;
- they cannot exist two Events superposed in the same worldpoint: all Events are unique identifiers;
- Past and Future light cones of other Events, at different spatial locations, have light cones which are offset from those of the Event we have arbitrarily designated as being at the origin;
- the areas where the Past and Future light cones of two Events overlap, are in their common Past and Future respectively, but each Event will have regions of spacetime from which they can receive and send Information that are not shared with the others.

What is a Triggered Event ?

Theory of Information point of view:

"devices to label the statuses of physical or logical entities"



▲ Qualitative evolution of the Hubble horizon (dashed line) and of the scale factor (solid curve). The time coordinate is on the vertical axis, while the horizontal axes are space coordinates spanning a two-dimensional spatial section of the cosmological manifold. The inflationary phase extends from t_i to t_f , the standard cosmological phase from t_f to the present time t_c . The shaded areas represent causally connected regions at different epochs. At the beginning of the standard evolution the size of the currently observed Universe is larger than the corresponding Hubble radius. All its parts, however, emerge from a spatial region that is causally connected at the beginning of inflation (abridged by Gasperini, 2007)

After 1915, with the advent of the General Relativity, the point of view changed sensibly. Every worldpoint is still the origin of the bicone of the active Future and the passive Past but:

- the two zones are no more separated by an intervening region of Events causally disconnected;
- it is possible for the cone of the active Future to overlap with that of the passive Past;
- it is possible to experience Events now that will in part be an effect of our future Events or decisions (Trigger and Measurement Events included).

Adding to General Relativity the Principle of General Covariance, Einstein made a precise statement about the fact that *global evolution does not exist*. From his point of view, *the time t is just a label we assign to one of the coordinate axes*. The figure presented in the precedent section titled: "*Events' causal connection. Introduction*" was published in 1973, before the discovery of the Inflationary mechanism by Starobinski, Linde and Guth. The figure above, on the opposite, includes also this phase and is the model considered *standard* from 1982 til ~1993. Here, the qualitative evolution of the Hubble horizon is showed into the couple of

dashed lines and of the scale factor with the external solid curve. The time coordinate is on the vertical axis, while the horizontal axes are space coordinates spanning a two-dimensional spatial section of the cosmological manifold. The inflationary phase extends from t_i to t_f , the standard cosmological phase from t_f to the present time t_c . The shaded areas represent causally connected regions at different epochs. At the beginning of the standard evolution the size of the currently observed Universe was larger than the corresponding Hubble radius.

All of its parts emerged from a spatial region which was causally connected at the beginning of inflation, implying that the causal connection is maintained also after the inflation.

It is important to understand the initial causal connection is what still today let a motor in the Blowformer Machine run following the same Physical Laws as the motor in the Palletiser, 150 m afar. The figure above also shows that there is a wide all-around sector which was causally connected but that receded so fast to have since long time moved out of our horizon. Then, disconnected also with respect to actual events.

Modern version post-2000

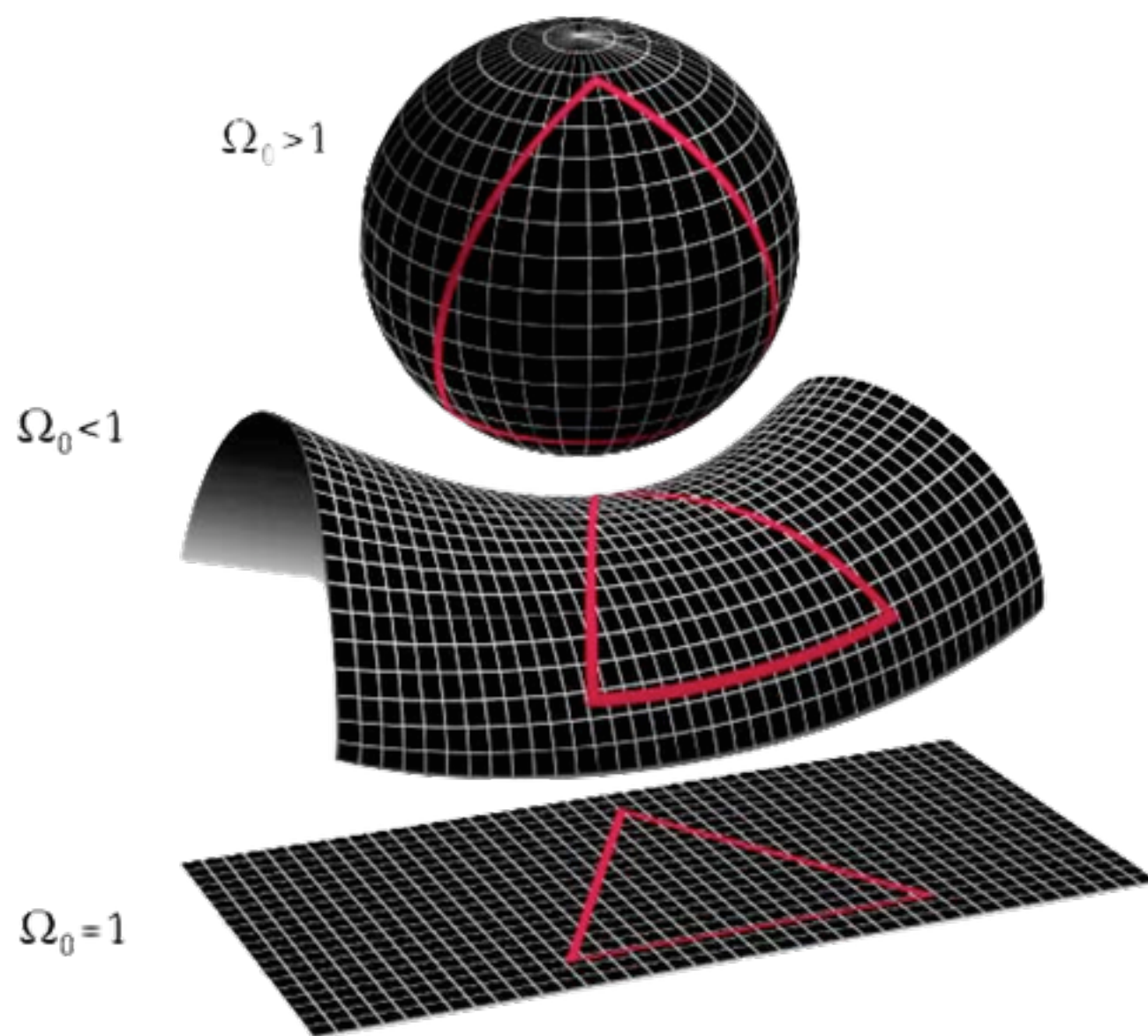
In the year 2000 T. Banks discovered that the mass density parameter Ω is determined as the inverse of the number N of degrees of freedom. Refer to the figure below: the curvature parameter Ω_0 encodes the system density, say the relation between (mass + energy) and volume. But, the volume strictly depends on the number of degrees of freedom. This is now considered an input parameter at the most fundamental level of physics. Shortly later, Raphael Bousso has been capable to derive a new definition, today standard, of *causal connection between Events*.

The perspective establishes the new concept of Causal Diamond, an example of these in the figure down, carrying on the scenario of everyday practical measurements (or Triggerings) evaluations of causal relation until a few years ago extremely theoretical. It is an approach looking to macroscopic (and not mesoscopic or microscopic) objects in the relativistic frame in which, as an example, also smartphones' GPS commonly operate. All what we'll refer for a Trigger is true also for measurement instruments like all the electronic inspections, like triggering nearly exclusively electromagnetic. Imagine that p and q are two points on an Trigger's world line, with q later than p. One can think of p as the beginning and q as the end of the Triggering (or, measurement).

Then, it is observed that the total Entropy is bounded by the inverse of the mass density and that it cannot be observed at all out of a small subset of the much wider bicone, say:

- increasing Entropy (second Law of Thermodynamics valid);
- to consider only the Trigger's (or, measurement instrument) causal Past and causal Future and ignore everything else.

The last is a sensible restriction: at the point q, the endpoint of the Triggering (or, measurement instrument), the Trigger can only have received signals from the Past of q. The rest of space-time has not yet been seen. For the purposes of the measurement in question, its Entropy is operationally meaningless and can be ignored. Also, the Trigger's Past is bounded by the Past light-cone from the point q, and that Signals within the Trigger's Past must pass through this cone.



Left side: curvature determines the sum of the inner angles of a triangle, which in the three cases here depicted shall be:

$\Omega_0 > 1$, Inner total angle $> 360^\circ$

$\Omega_0 < 1$, Inner total angle $< 360^\circ$

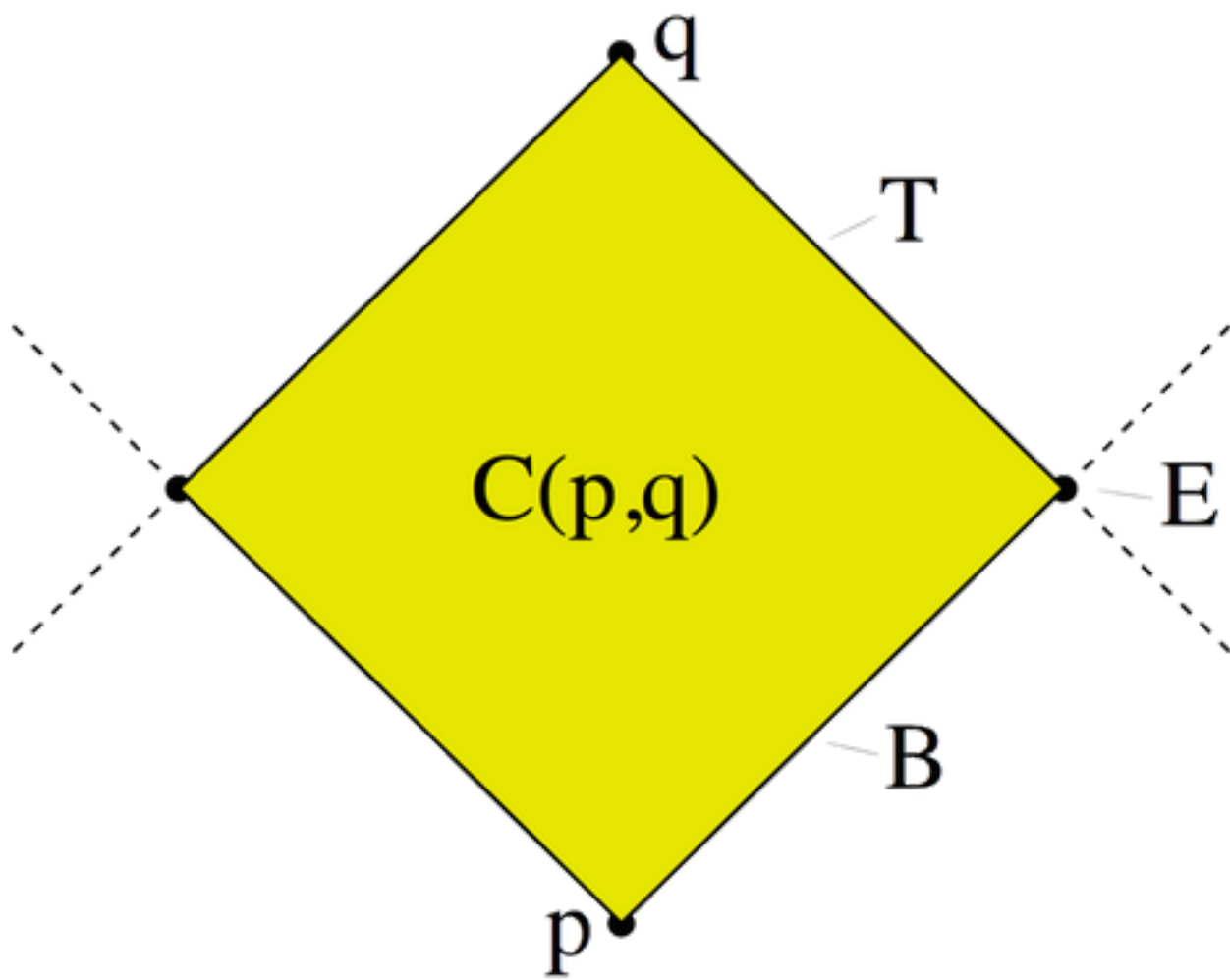
$\Omega_0 = 1$, Inner total angle $= 360^\circ$

Matter plus energy density parameter Ω_0 is translated in a spatial curvature. Curvature depending by the number of degrees of freedom of the system. From this discovery of the year 2000 it has been possible to derive a new definition of Causal Connection between Events, close to everyday measurements, referred to our macroscopic scale. Causal connection exists only between points in a small subspace of the bicone. This, in turn, implies that the Environment, much smaller than expected, cannot be ignored

Thus, if one wishes to encounter the boundary of the observable Entropy, it will be sufficient to bound the Entropy on the Past light-cone of the endpoint, q. It is not enough for Entropy (or, Information) to lie in the Trigger's Past. To be observed, it actually has to get to the Trigger, or at least to a region that can be probed by the Trigger. But, a measurement that starts at p can only detect what lies in the causal Future of p.

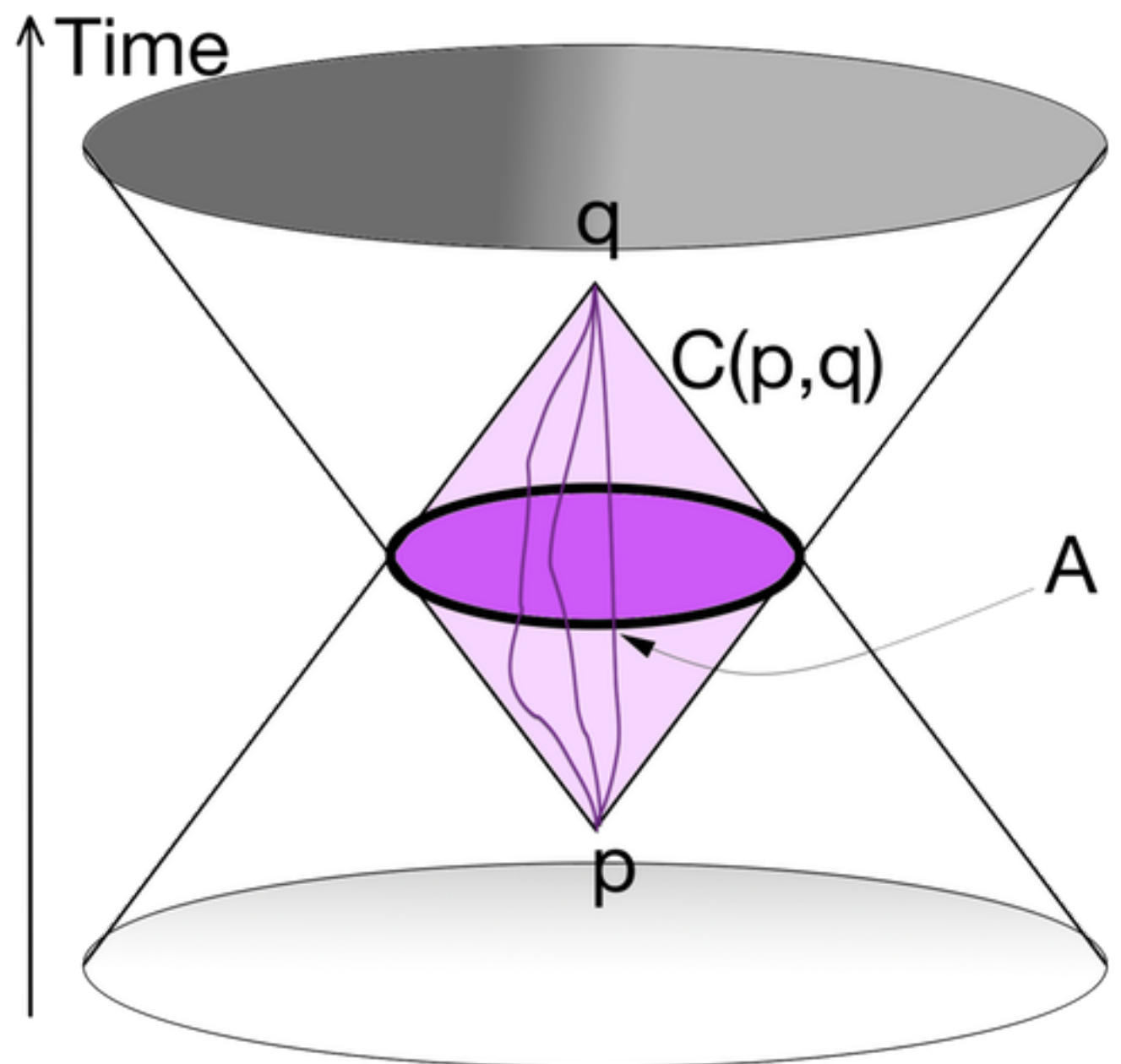
In this modern perspective it is implicit that p and q are joined by *at least one* world-line, which corresponds to both points of view, classic Hamiltonian and modern Quantum Mechanical, following which, to go from a point in the Past to a point in the Future, different paths are:

- possible (Hamiltonian perspective);
- actual (Quantum Mechanical perspective).



Left side: a bidimensional lateral cut of the Causal Diamond. After 1990, Multiverse replaced the classic concept of Universe: a multitude of coexisting non-communicating bicones and new Events, derives by each one single Event. Each one of the infinite yellow colour dots in the image, is part of the paths followed by the object to move itself from the point p to q in the Future of p (abridged by image R. Bousso, 2000)

Right side: Causal Diamond in three dimensional view with two space dimension plus a time. In the example, Past and Future light cones (light violet colour) are super imposed around a 3D sphere here depicted as a dark violet circle because the third spatial dimension we cannot show. The light violet volume named *causal diamond*, after 2000 became a portion smaller than the entire bicone in 1907 imagined causally related. The oblique lines represent three of the infinite paths joining p and q. Each one path a different 'history' in the sense attributed by Feynman (abridged by image R. Bousso, 2000)



In the figure above, then we are showing three of the infinite and actual worldlines conceived by Quantum Mechanics. What now may appear obscure shall become more clear in the following sections. If q is in the Future of p, there will be several world lines connecting them, otherwise the entire region $C(p,q)$ will be empty or degenerate.

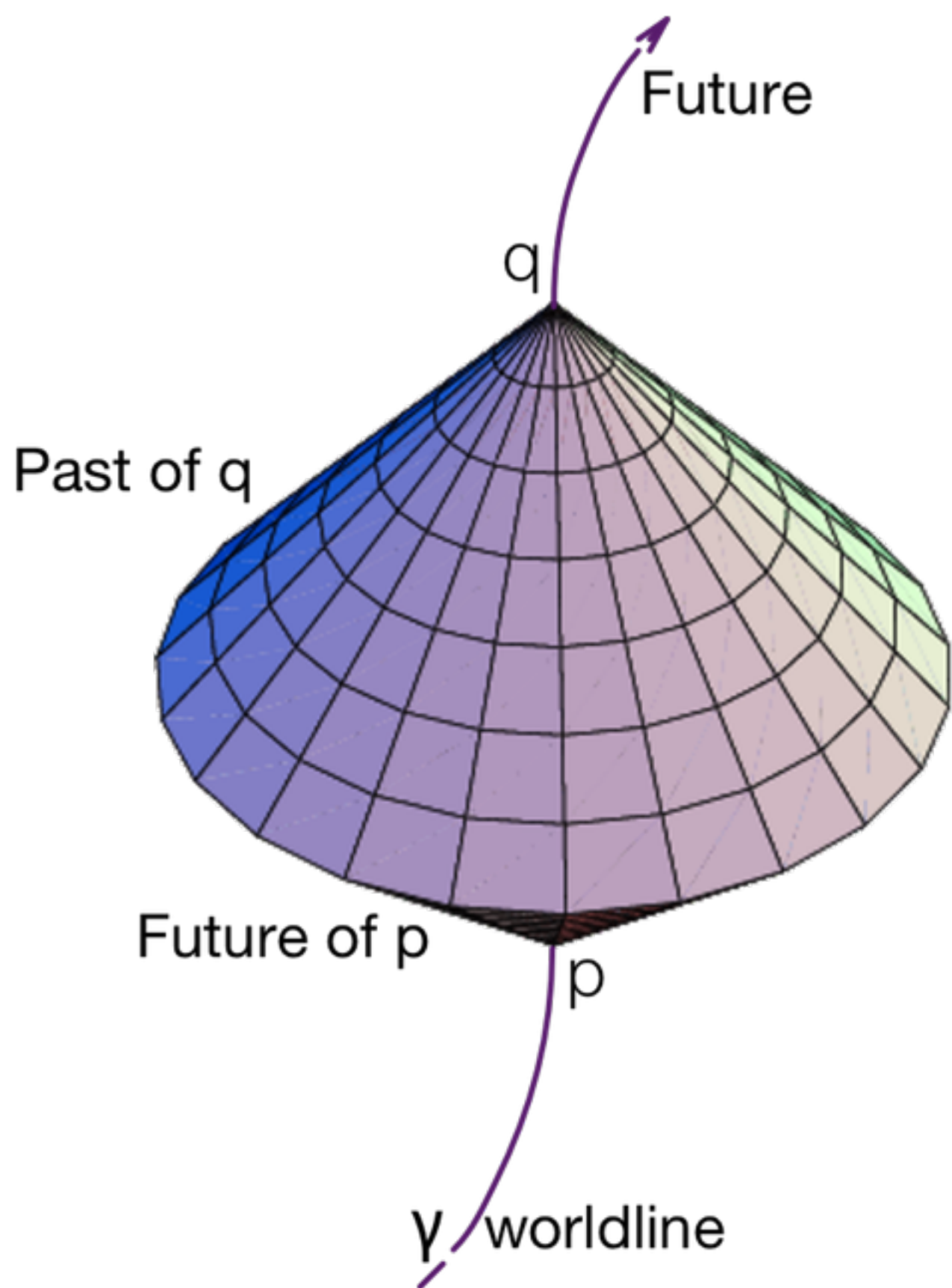
The descriptions visible in the figures above, below, and on right side are named Causal Diamonds:

- above, their derivation by the wider Minkowski causal bicone, in a 3-D geometry;
- on right side, what happens in the 2-D yellow colour region (a lateral cut of the 3-D Causal Diamond) of the form $C(p,q)$ for some pair of points (p,q).

- below, the only Causal Diamond in a 3-D geometry, and there is not to forget they are objects whose dimension is ≥ 4 .

They can describe separate causal diamonds if they are contained in a single larger causal diamond. Causal Diamonds are bounded by a:

- top cone, a portion of the Past light-cone of q;
- bottom cone, a portion of the Future light-cone of p;



Left side: a 3-dimensional view of the Causal Diamond. These spaces have dimension ≥ 4 . In evidence the worldline γ passing through the point p and proceeding toward the future at q. The tetravolume into a Causal Diamond is however huge if we consider that the wave packets of light (and of the curvature of the spatial geometry, gravitons) had available more (12 - 18) billions of years of time to propagate themselves (image abridged by Wolfram Research)

occupying this way the entire subset of points into the (pink coloured) bicones in the couple of figures above.

The cones usually intersect at a two-dimensional spatial surface A (see the upper figure above), the edge of the Causal Diamond. In any case, the Entropy in the Causal Diamond must pass through the top cone and, we repeat, all Signals must have entered through the bottom cone. The net result of this line of reasoning is that the Entropy within a Causal Diamond is under strict theoretical control and the tetradimensional volume is much smaller than what it was conceived in 1907. Being much smaller, causal relation inferences becomes closer to the scales of dimensions and durations of our everyday measurements.

Examples of Events’ causal connection

Triggering of containers by mean of Laser light

Events' causal connection, in its classic version pre-2000, encounters an important field of application with respect to the exchange of light signals. This, in the Electronic Inspectors is commonly associated to Triggering of typically accelerated and fast moving containers. In the following, we'll outline the true rigorous scenario around a Triggering. This is useful to understand why Triggering, an action strictly related to the kinematic of a container, results on the opposite always referred to an external speed reference, since decades an Encoder. This, when it is well known that only direct measurements provide absolute values, those whose relative errors are minimised. The choice toward external speed references is forced by the complexity of internal (direct) measurements. To use an Encoder, speaking the language of modern Physics, means to coarse-grain the container position into a Shifting-Register cell. It is a coarse-graining operation because the Shifting-Register cell has typically an extension (along the container direction of movement) bigger than a container diameter. Coarse-graining, for definition, is clearly not a synonymous of increase on precision, just the opposite, and in our case kinematic uncertainty means False Rejects. Curvature effects described below are in the Shifting-Register *emulated* and widely reinforced by accelerations and decelerations of Conveyors and by the contacts of the container with the lateral guides causing container sliding.

What should happen if we'd be measuring containers' speed in a direct rigouros way ?

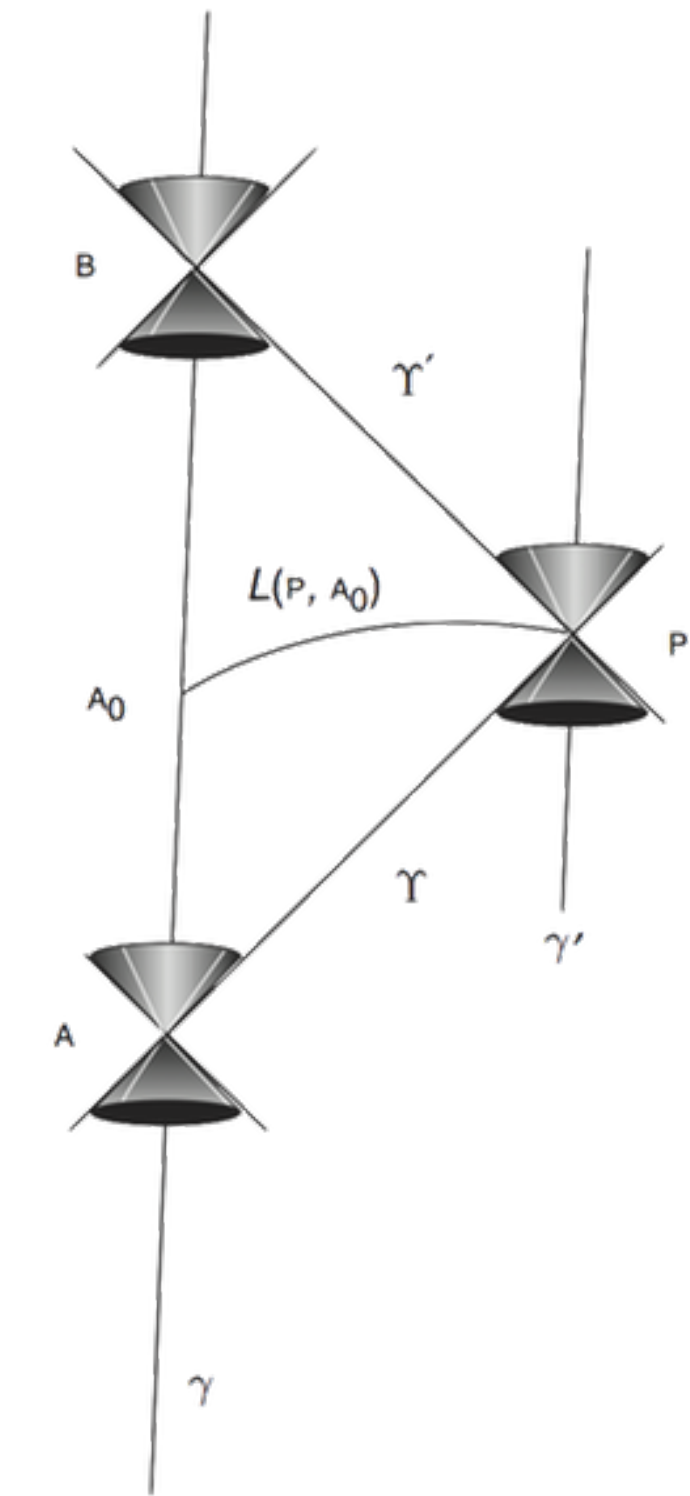
Example 1. Exchanging light signals

Triggers, in the most general and real case, operate in the Factory accelerated reference frame, meaning they operate along worldlines which are not geodetic nor orbits. Because of this reason the Trigger has to be considered in motion along a curve γ (see figure on right side) with tangent vector u and proper time s as parameter. What follows is referred to direct reflection Trigger photosensors, however valid also for the widespread thru-beam Trigger photosensors. This last case carries similar results, because also the interruption of the light beam is not instantaneously received by the Trigger u on the worldline γ . By mean of the Trigger, the CPU processing the informations encoded in the electric signals infeeding by the Trigger, on the base of a dedicated software routine, can only deduce the spatial velocity of a passing container relative to its own local rest frame.

Meaning, by the exchange of light signals:

- at the event A on γ the Trigger sends a light signal to the container, which receives it at the event P on γ' ;
- at P the light signal is reflected back to the Trigger which receives it at the Event B on γ .

The Line from P to A_0 is curved to indicate the fact that the spacetime itself is curved. Denote as Y and Y' the null geodesics connecting A to P and P to B respectively. Let A_0 be the event on γ , subsequent to A and antecedent to B, which is simultaneous with P with respect to the Trigger u and such that the space-like geodesic $\zeta_P \rightarrow A$ joining P to A_0 is extremal with respect to γ . Repeated reading of the time of emission of light signals at A and of the time of recording of the reflected echo at B allows one to determine the length of the space-like geodesic segment connecting P to A_0 , which represents, by definition, the instantaneous spatial distance of the container at P from the Trigger on γ like in the see the figure on right side. The relative velocity of the container with respect to the Trigger u is then deduced, differentiating the above spatial distance with respect to the Trigger's proper time. The relative velocity so determined is



▲ Exchange of light beams between Trigger and container, to determine container's kinematics

along the Trigger’s local line of sight, so it is a radial velocity, as an example, a velocity either of recession or of approach. The measurement process involving the events A, P, and B is non-local insofar as the measurement domain is finite.

Example 2. Doppler shift

An alternative way to measure the container velocity is based on the measurement of a frequency shift of the exchanged photons through the application of the Doppler formula. The image on right side hints to the process. But, the velocity so determined, should be an equivalent velocity because the frequency shift can also be caused by geometry perturbations. Something unrelated to the container’s motion.

As already stated, curvature effects are in general entangled with inertial terms resulting from the choice of the reference frame, so we shall just term as curvature any possible combination of them. The measurement of a relative velocity is the result of a local measurement, which does not contain curvature terms, and a nonlocal one, which depends explicitly on the curvature.

